<u>Attachment 4</u>

TECHNICAL MEMORANDUM

TO:	TERRY DESMARAIS DEAN PESCHEL DAVID GREEN	DATE:	NOVEMBER 11, 2013
FROM:	THOMAS W. GALLAGHER CRISTHIAN MANCILLA	RE:	CALIBRATION OF GREAT BAY ESTUARY HYDRODYNAMIC MODEL AND INCREMENTAL NITROGEN ESTIMATION
		FILE:	337-200951-007

1.0 INTRODUCTION

This technical memorandum summarizes the completion of the calibration of a hydrodynamic model of the Great Bay Estuary System (GBES) originally started as part of the Squamscott River modeling study. The Squamscott River modeling study was discontinued when it was realized that excessive levels of algae in the Exeter wastewater lagoons discharge had a significant effect on Squamscott River water quality. Because Exeter plans to upgrade its wastewater treatment system and eliminate excessive algal levels in its effluent discharge, it was decided not to develop a hydrodynamic water quality model with Squamscott River water quality data that is so atypical and different than expected future river water quality after the Exeter wastewater treatment system upgrade. However, it was recognized that the completion of the hydrodynamic model of the GBES would provide a useful tool for the cities of Dover, Rochester, and Portsmouth to relate present and future wastewater effluent nitrogen discharges to increases in GBES nitrogen levels. The following is a brief description of the hydrodynamic model framework and calibration analysis against salinity, temperature, and tidal elevation measurements at various locations throughout the GBES. Later sections in this document summarize the application of the GBES calibrated hydrodynamic model in computing incremental nitrogen levels in the Estuary as a result of multiple effluent nitrogen scenarios.

2.0 HYDRODYNAMIC MODEL FRAMEWORK

The transport and mixing of pollutant loads introduced to rivers, lakes, reservoirs and coastal environments are controlled by the circulation characteristics of the receiving water body. The fate of a pollutant is strongly influenced by turbulent mixing created by the surface wind stress, currents and tides (astronomical or meteorological). At the same time, turbulent mixing leads to horizontal dispersion in the longitudinal and lateral directions, and to vertical dispersion throughout the water column. Coupled with turbulent mixing due to wind and currents are heat exchange processes between the water column and the atmosphere. All these mechanisms determine the spatial extent and magnitude of the pollutant. The processes that control the heat exchanges between the water and atmosphere are well documented (Ahsan and Blumberg, 1999; Cole and Buchak, 1995). The four major heat flux components, short-wave solar radiation, long-wave atmospheric radiation, sensible (conduction) and latent (evaporation) heat exchange used are based on the formulae reported in Ahsan and Blumberg (1999). The complexity of the physical processes governing the evolution of an introduced constituent, such as a pollutant load, suggests the use of sophisticated hydrodynamic models. For this study, HydroQual's far-field hydrodynamic model (ECOMSED) has been applied to the Great Bay Estuary System.

The hydrodynamic model is a three-dimensional, time-dependent, estuarine and coastal circulation model developed by Blumberg and Mellor (1987). The model incorporates the Mellor and Yamada (1982) level 2-½ turbulent closure scheme to provide a realistic parameterization of vertical mixing. A system of curvilinear coordinates is used in the horizontal direction, which allows for a smooth and accurate representation of variable shoreline geometry. In the vertical scale, the model uses a transformed coordinate system known as the σ-coordinate transformation to allow for a better representation of bottom topography. Water surface elevation, water velocity in three dimensions, temperature and salinity, and water turbulence are predicted in response to weather conditions (winds and incident solar radiation), tributary inflows, tides, temperature and salinity (if applicable) at open boundaries connected to the water body.

The model has gained wide acceptance within the modeling community and regulatory agencies as indicated by the number of applications to important water bodies around the world. Among these applications are: Delaware River, Delaware Bay, and adjacent continental shelf (Galperin and Mellor 1990a,b), the South Atlantic Bight (Blumberg and Mellor, 1983), the Hudson Raritan estuary (Oey et al., 1985a,b,c), the Gulf of Mexico (Blumberg and Mellor, 1985), Chesapeake Bay (Blumberg and Goodrich 1990), Massachusetts Bay (Blumberg et al., 1993), and most recently in St. Andrew Bay (Blumberg and Kim, 2000), New York Harbor and Bight (Blumberg et al, 1999) and Onondaga Lake (Ahsan and Blumberg 1999). In addition, the model has been applied in Perdido Bay and Escambia/Pensacola Bay (FL) as part of the water quality projects in these systems. The model has also been applied in several lake environments such as Lake Michigan and Green Bay (HydroQual, 1999), and Milwaukee Harbor and near shore Lake Michigan (HydroQual, 2007). In all these studies, model performance was assessed by means of extensive comparisons between predicted and observed data. The predominant physics were realistically reproduced by the model for this wide range of applications.

The model solves a coupled system of differential, prognostic equations describing the conservation of mass, momentum, temperature, salinity, turbulence energy and turbulence macroscale. The governing equations for velocity $U_i = (u, v, w)$, temperature (T), salinity (S), and $x_i = (x,y,z)$ are as follows:

$$\frac{\partial U_i}{\partial x_i} = 0 \tag{3-1}$$

$$\frac{\partial}{\partial t}(U,V) + \frac{\partial}{\partial x_i}\left[U_i(u,v) + f(-v,u)\right]$$
$$= -\frac{1}{\rho_o}\left[\frac{\partial P}{\partial x},\frac{\partial P}{\partial y}\right] + \frac{\partial}{\partial z}\left[K_M \frac{\partial}{\partial z}(u,v)\right] + \left(F_U, F_V\right) \tag{3-2}$$

$$\frac{\partial T}{\partial t} + \frac{\partial}{\partial x_i}\left(U_i T\right) = \frac{\partial}{\partial z}\left[K_H \frac{\partial T}{\partial z}\right] + F_T \tag{3-3}$$

$$\frac{\partial S}{\partial t} + \frac{\partial}{\partial x_i}\left(U_i S\right) = \frac{\partial}{\partial z}\left[K_H \frac{\partial S}{\partial z}\right] + F_S \tag{3-4}$$

The horizontal diffusion terms, (F_U, F_V), F_T and F_S, in Equations (3-2) through (3-4) are calculated using a Smagorinsky (1963) horizontal diffusion formulation (Mellor and Blumberg, 1985). Under the shallow water assumption, the vertical momentum equation is reduced to a hydrostatic pressure equation. Vertical accelerations due to buoyancy effects and sudden variations in bottom topography are not taken into account. The hydrostatic approximation yields:

$$\frac{P}{\rho_o} = g(\eta - z) + \int_z^{\eta} g\,\frac{\rho' - \rho_o}{\rho_o}\,dz' \tag{3-5}$$

where P is pressure, z is water depth, η(x,y,t) is the free surface elevation, ρ_o is a reference density, and $\rho = \rho(T,S)$ is the density. For this study salinity is considered zero.

The vertical mixing coefficients, K_M and K_H, in Equations (3-2) through (3-4) are obtained by appealing to a level 2-½ turbulence closure scheme and are given by:

$$K_M = \hat{K}_M + \upsilon_M,\ K_H = \hat{K}_H + \upsilon_H \tag{3-6}$$

$$\hat{K}_M = q\ell S_M,\ \hat{K}_H = q\ell S_H \tag{3-7}$$

where $q^2/2$ is the turbulent kinetic energy, l is a turbulence length scale, S_M and S_H are stability functions defined by solutions to algebraic equations given by Mellor and Yamada (1982) as modified by Galperin et al. (1988), and υ_M and υ_H are constants. The variables q^2 and l are determined from the following equations:

$$\frac{\partial q^2}{\partial t} + \frac{\partial (uq^2)}{\partial x} + \frac{\partial (vq^2)}{\partial y} + \frac{\partial (wq^2)}{\partial z} = \frac{\partial}{\partial z}\left[K_q \frac{\partial q^2}{\partial z}\right]$$

$$+ 2K_M\left[\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2\right] + \frac{2g}{\rho_o} K_H \frac{\partial \rho}{\partial z} - 2\frac{q^3}{B_1 \ell} + F_q \qquad (3\text{-}8)$$

$$\frac{\partial (q^2\ell)}{\partial t} + \frac{\partial (uq^2\ell)}{\partial x} + \frac{\partial (vq^2\ell)}{\partial y} + \frac{\partial (wq^2\ell)}{\partial z} = \frac{\partial}{\partial z}\left[K_q \frac{\partial (q^2\ell)}{\partial z}\right]$$

$$+ E_1\ell\left\{K_M\left[\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2\right] + \frac{g}{\rho_o} K_H \frac{\partial \rho}{\partial z}\right\} - \frac{q^3}{B_1 \tilde{\omega}} + F_\ell \qquad (3\text{-}9)$$

where $K_q = 0.2q\ell$, the eddy diffusion coefficient for turbulent kinetic energy; F_q and F_ℓ represent horizontal diffusion of the turbulent kinetic energy and turbulence length scale and are parameterized in a manner analogous to either Equation (3-6) or (3-7); $\tilde{\omega}$ is a wall proximity function defined as $\tilde{\omega} = 1 + E_2 (\ell/\kappa L)^2$, $(L)^{-1} = (\eta - z)^{-1} + (H + z)^{-1}$, κ is the von Karman constant, H is the water depth, η is the free surface elevation, and E_1, E_2 and B_1 are empirical constants set in the closure model.

The basic Equations, (3-1) through (3-9), are transformed into a terrain following σ-coordinate system in the vertical scale and an orthogonal curvilinear coordinate system in the horizontal scale. The resulting equations are vertically integrated to extract barotropic variables, and a mode splitting technique is introduced such that the fast-moving, external barotropic modes and relatively much-slower internal baroclinic modes are calculated by prognostic equations with different time steps. Detailed solution techniques are described in Blumberg and Mellor (1987) and ECOM Users Manual (HydroQual, 2007).

The Great Bay consists of a vast area of tidal wetlands. Most of the southeast side of the Great Bay is submerged under average tidal conditions. Water storage that occurs in the wetlands during tidal cycling is expected to have an effect on hydrodynamic transport through much of the study area. These processes of wetting and drying need to be explicitly considered in hydrodynamic model calculations. An algorithm, based upon Flather and Heaps (1975) and Kim (1999), that permits the model to simulate the flooding and drying of tidal flats was incorporated into ECOMSED. The treatment is based on both total water depth ($D = H + \eta$) and elevation gradient with adjacent grid cells. For implementation of the flooding and drying scheme, a minimum threshold depth (D_{min})

and a critical elevation gradient (ε) are pre-assigned (via model input). Testing of the wetting/drying scheme has been conducted under various water bodies (i.e. Jamaica Bay, Hackensack River, etc.) and confidence has been established in application of this algorithm to the Great Bay hydrodynamic model.

3.0 HYDRODYNAMIC MODEL DEVELOPMENT

3.1 Model Configuration

The hydrodynamic model domain included the Great Bay Estuary System (Great Bay, Little Bay, the Upper and Lower Piscataqua River) and the tidal part of its tributaries (Squamscott River, Lamprey River, Winnicut River, Oyster River, Bellamy River, and Cocheco River). In addition, a 6 mile by 18 mile area of the adjancent coastal zone off the City of Portsmouth was included in the model. A map of the model grid is shown in Figures 1 and 2. The model domain consists of 68 x 161 cells in the horizontal direction with varying grid sizes. As shown in Figure 1, the model cells have a horizontal resolution of about 800 to 2000 m in the offshore area. To properly resolve the lateral variability of the Great Bay, grid cells vary from about 100 to 200 m within the Great Bay. The Great Bay itself is represented by about 45 x 20 horizontal grid cells. Figure 2 shows a detailed view of the computational grid in the Great Bay and Little Bay area. The grid cells in the tributaries are about 100 m in length and resolved with a single grid cell where the river becomes narrow, less than 100 m wide.

The model grid system has 10 equally spaced σ-layers in the vertical direction. The model bathymetry was determined based on various sources: USACE survey data in the tributaries and entrance to the Portsmouth Harbor, NOAA Electronic Nautical Charts in the coastal areas, detailed bathymetry survey data in the Great Bay collected by the Center for Coastal and Ocean Mapping (CCOM) in 2009, and detailed bathymetry survey data in the Squamscott River collected in the summer of 2011 by HYDROTERRA.

3.2 Model Forcing Functions

The boundary forcing functions of the hydrodynamic model consist of:

1. Water surface elevation along open ocean boundaries incorporating astronomical tide and low frequency variations of sea surface elevation;
2. Temporal variations of temperature and salinity along the open boundaries;
3. Freshwater inflows from rivers and wastewater treatment plants; and
4. Meteorological information consisting of wind speed and direction, shortwave solar radiation, cloud cover, air temperature, atmospheric barometric pressure and relative humidity to compute surface wind stress and heat flux.

The details of these boundary conditions are described in this section.

Open Ocean Boundaries (Elevation, Temperature, Salinity)

Model forcing data at the open boundaries in the Gulf of Maine was obtained from the NOAA tide gage station at Fort Point, which is located at the mouth of Portsmouth Harbor. Hourly water elevations observed at this tide station were used to drive the model. For the temporal variation of the offshore boundary water temperature and salinity, measured values at Fort Point and a nearby NOAA station in Portland, ME were used. A fixed salinity value of 30 psu was assigned at the open boundaries throughout the modeling period. Figures 3 and 4 show the open boundary conditions for 2010 and 2011.

Freshwater Sources

There are six USGS flow gages located in the tributaries in the study area: Lamprey, Exeter, Oyster, Cocheco, Salmon Falls, and Winnicut Rivers. The six gages are summarized in Table 1. The scale factors in Table 1 indicate the factor employed to compute each tributary's total flow contribution, accounting for the drainage areas below the gages to each river's mouth. There is no flow gage at the Bellamy River and therefore a flow estimate was developed. Drainage area for the Bellamy River lies between the Cocheco and Oyster Rivers. Gaged flow at the Oyster River was used to estimate the Bellamy River by applying a ratio of drainage areas (0.686). The Salmon River flow gage was discontinued in 2005. Initially, Salmon River flow estimates were developed based on measured Cocheco River flows and considerations for the controlled nature of these rivers. Fortunately, during the model calibration stage of this study, the NHDES Dam Bureau was able to provide measured flow data at the Milton 3 Ponds Reservoir. Total flows used in the model for 2010 and 2011 are shown in Figure 5 and 6. Table 2 presents a summary of the flows at these locations. In general, the statistics of the flows indicate that similar annual mean flows were observed at all tributaries for both years. However, there were more high and low flow events in 2010 as compared to 2011.

In addition to river flows, the hydrodynamic model includes freshwater flows from the major sewage treatment plants (STP) in the study area. Table 3 lists the coordinates and freshwater discharge rates of these STPs and Figure 7 shows their corresponding locations.

Meteorological Data

Meteorological data observed at the Pease International Tradeport Airport was used for the modeling study. Hourly wind data as well as air temperature, relative humidity, sky cover, and barometric pressure data for the years 2010 and 2011 were obtained from the NOAA. Figures 8 and 9 show the meteorological data used for this study. The shortwave radiation shown in the figures are computed values based on the observed cloud cover data at the NOAA station.

4.0 HYDRODYNAMIC MODEL CALIBRATION

Model calibration was performed utilizing field monitoring data collected at various locations in the Great Bay Estuary system. There were seven water quality monitoring stations operating in the years 2010 and 2011: Coastal Marine Lab near Fort Point at the entrance to the Portsmouth Harbor; Salmon Falls River, Great Bay, Bellamy River, Oyster River; and another station located at the mouth of Squamscott River. These monitoring stations are shown in Figure 10. There are two monitoring stations in the middle of Great Bay; one managed by the University of New Hampshire and another one managed by the Centralized Data Management Office (CDMO) of the National Estuarine Research Reserve System (NERRS). The temperature and salinity data observed at these stations is shown in Figures 11 to 14. A careful review of the data suggests that at certain times the data sensors were not operating correctly. These periods are marked in the figures as shaded areas.

Temperature

Comparisons of computed and observed water temperature in 2010 and 2011 at seven monitoring locations are shown in Figures 15 and 16, respectively. Red lines indicate observed water temperature and blue and green lines indicate the model computed water temperature at surface and bottom, respectively. The figures show that the model computed water temperature tracks very well with data over the seasonal warming and cooling cycle in the study area as well as sudden rises and drops associated with atmospheric heating and cooling processes for both years. The model computed heat flux exchange processes based on the meteorological data observed at the Pease International Airport accurately calculated the water temperatures in the study area.

Salinity

Figures 17 and 18 show the comparison of model computed and observed salinity at the same seven monitoring locations for 2010 and 2011, respectively. The figures show that model computed salinity compares very well with the observed salinity at all stations. Salinity increase and decrease due to river inflow events are very well captured by the model. Model computed salinity indicates that the salinity may decrease to below 5psu during high flow events in the middle of Great Bay and increase to above 25psu during low flow conditions. While the data are not available during these high flow events that occurred in cold months when sampling is suspended, the computed and observed salinity agrees well during intermediate flow events such as in May and October 2011 periods (Figure 18).

The figures indicate that some stations show much higher variability of the salinity than other stations. Both, the observed and computed salinity at Lamprey River and Squamscott River stations, show higher variability (more than 15 psu) than those at the middle of the Great Bay, Oyster River and Salmon Falls River stations. This is due to the level of horizontal gradient of the salinity at each particular location. For example, at Squamscott and Lamprey stations, incoming high tides bring in higher salinity water from the Great Bay and on reversing cycles during the low tide, the outgoing tides carry the lower salinity water from the upstream location. Whereas within the Great Bay proper, salinity remains relatively uniform spatially, and therefore, intra-tidal variation of salinity remains relatively flat.

Both the observed and computed salinity at the Coastal Marine Lab, which is located at the entrance to the Portsmouth Harbor, show that salinity remains at around 30psu most of the time except during high flow periods. The model computed salinity tracks the range of salinity decrease during high flow periods and the returning back to higher salinity during low flow periods very well.

5.0 CALCULATION OF WWTPs PERCENT EFFLUENT IN THE GBES

The calibrated hydrodynamic model was employed to compute Dover, Rochester, Portsmouth and Pease WWTPs percent effluent at several locations across the GBES. Figure 19 presents these locations and their corresponding location IDs. Percent effluent values were computed by assigning a tracer concentration equal to 100 to each WWTP effluent flow and extracting model computed concentrations at all desired locations (one independent model scenario run for each WWTP). Rochester WWTP is located several miles upstream of the GBES but for modeling purposes this discharge was positioned at the Cocheco River upstream model boundary (the most downstream dam location on this river). NHDES has estimated a 25% nitrogen attenuation factor for Rochester WWTP (loss in transit to the Estuary) and therefore a 25% reduction was applied to the computed Rochester WWTP percent effluent values. Tables 4a and 4b present the 2010-2011 average percent effluent for current and design effluent flow conditions for each WWTP included in this analysis. The percent effluent computed by the model represents the fraction of the effluent that reaches the selected GBES locations as a result of dilution due to tributary freshwater flows, dilution due to ocean water and the local tidal dynamics.

6.0 ESTIMATION OF CONTRIBUTION OF WWTPs EFFLUENT NITROGEN TO GBES TN AND DIN

The WWTPs percent effluent computed by the hydrodynamic model at each selected GBES location was employed to estimate the incremental total nitrogen (TN) and dissolved inorganic nitrogen (DIN) under three effluent nitrogen loading scenarios: current conditions, monthly effluent TN=8 mg/L and monthly effluent TN=3 mg/L. A long term effluent TN of 6 mg/L and 3 mg/L were assumed to correspond to monthly effluent concentrations of 8 mg/L and 3 mg/L, respectively. When available, limited effluent data was employed to determine the corresponding DIN effluent concentrations for all three effluent nitrogen loading scenarios. For this calculation a GBES background TN of 0.3 mg/L and DIN of 0.1 mg/L was assumed. Tables 5 to 8 present the 2010-2011 average incremental TN (delta TN) for current and design effluent flow conditions for each WWTP included in this analysis. Tables 9 to 12 present similar information but for DIN. Figures 20 to 23 present a graphical representation of the incremental TN and DIN, under current effluent flow conditions, summarized in tables 5 to 12 but only for four selected GBES locations. Figures 24 to 27 present similar graphical representations but for design effluent flow conditions.

An additional incremental nitrogen analysis was performed to estimate the total TN and DIN decrease in Great Bay when all WWTPs reflect each nitrogen reduction scenario (monthly effluent TN=8 mg/L and TN=3 mg/L). For the purpose of this analysis, Exeter, Newmarket and Durham WWTPs were also included in the incremental nitrogen calculations. Table 13a presents the 2010-2011 average incremental TN for current effluent flow conditions due to all WWTPs considered in this analysis. Table 13b presents similar information but for DIN. This analysis results are also presented graphically for selected locations in Figure 28.

A possible application of the previous incremental nitrogen analysis is the estimation of Great Bay DIN levels after the implementation of each nitrogen reduction scenario by using recent measured DIN levels. Measured DIN levels at station GRBAP (Adams Point between Great Bay and Little Bay) reflect an average of 0.10 mg/L and 0.17 mg/L for the 1974-1981 and 1992-2011 periods, respectively (PREP, 2012). The 1992-2011 measured DIN levels were decremented by the difference between the computed incremental DIN under current effluent DIN conditions and incremental DIN under each effluent DIN reduction scenario. The computed incremental DIN at the Great Bay location (ID 14) was employed for this analysis. Figure 29 presents both time periods measured average DIN levels and the resultant DIN levels for the 1992-2011 period when all WWTPs implement both nitrogen reduction scenarios (under current effluent flow conditions).

7.0 GBES FLUSHING TIME

The GBES hydrodynamic model can be used to estimate the rate at which various segments of the GBES are flushed. As an example, hydrodynamic model runs were performed to estimate the flushing time of Great Bay (proper Great Bay defined as the area encompassed between the Lamprey, Squamscott and Winnicut river mouths and Little Bay's south boundary) for low and high river flow conditions. In this analysis flushing time is derived from a modeling run in which the initial concentration of a conservative substance for all of Great Bay is assigned at 100 mg/L. The model is run for a period of 15 days and the fraction of initial conservative substance mass in Great Bay is plotted as a fraction of time. The results for low river flow conditions of approximately 100 cfs (September 2010) are plotted in Figure 30. In the top panel the model simulation is started at slack before flood. The fraction of initial mass in Great Bay fluctuates with the tides, but steadily decreases with time. One definition of flushing time is the time it takes to reduce the mass of the conservative substance to 0.37 (1/e) of the value at the beginning of the model simulation. Using this definition, the flushing time for the Great Bay is estimated at 7 days. All model runs were performed near neap tide conditions. The same analysis is performed with initial conditions at slack before ebb and the results are shown on the bottom panel of Figure 31. Under these conditions the flushing time of Great Bay is estimated at 4 days. A similar analysis is presented on Figure 29 for high river flow conditions of approximately 1,000 cfs (February 2010). The estimated Great Bay flushing times are estimated between 2.5 and 4.5 days. Although this analysis is intended as an example, it clearly shows that the flushing time in Great bay is less than a week and at times as little as a few days. This limited flushing time in Great Bay is the principal factor limiting the accumulation of algae in Great Bay. Algae grown in Great Bay are tidally flushed into the deeper segments of the GBES where conditions are unfavorable for significant algal growth.

8.0 REFERENCES

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TABLES

Table 1. Summary of USGS Gages

Location	Gage #	Period of Flow Record	Drainage Area (mi^2)	Scale Factor
Lamprey near Newmarket	01073500	1934-present	183.0	1.168
Exeter at Haigh Road (Squamscott)	01073587	1996-present	63.5	1.995
Oyster near Durham	01073000	1934-present	12.1	1.564
Cocheco near Rochester	01072800	1995-present	85.7	2.159
Salmon Falls at Milton	01072100	1968-2005	108.0	3.093
Winnicut at Greenland	01073785	2002-present	14.1	1.333

Table 2. Modeling Period Flow Summary (Annual Average & Range, Unit: cfs)

Year	2010	2011
Lamprey	440 (4 - 7650)	438 (13 - 2254)
Squamscott	289 (2 - 5347)	297 (7 - 2114)
Oyster	73 (1 - 1674)	66 (2 - 572)
Cocheco	364 (10 - 6563)	421 (13 - 2957)
Salmon Falls	762 (27 - 6927)	811 (62 - 2961)
Winnicut	50 (1.2 - 1140)	42 (0.8 - 457)
Bellamy	19 (0.3 - 448)	17 (0.5 - 153)

Table 3. Sewage Treatment Plants Included in the Modeling Study

Name	Longitude, West	Latitude, North	Flow (MGD)	Water Bodies
Exeter	70.93523	42.996477	2.25	Squamscott River
Newfields	70.935230	43.037960	0.07	Squamscott River
Newmarket	70.933979	43.075730	0.70	Lamprey River
Durham	70.903114	43.133975	1.11	Oyster River
Dover	70.831295	43.158058	3.34	Upper Piscataqua River
Rochester	70.965425	43.267495	3.92	Cocheco River
Portsmouth (Peirce Island)	70.739497	43.073145	5.90	Lower Piscataqua River
Pease	70.790490	43.103000	0.53	Lower Piscataqua River

Table 4a. Computed % Effluent in the Great Bay Estuary System (Feb 2010 - Dec 2011) Current Effluent Flows

Dover WWTP	
Effluent Flow (MGD)=	3.3
Location	**% Effluent**
Salmon Falls River (10)	0.077
Upper Piscataqua River (9)	0.184
Upper Piscataqua River (8)	0.482
Upper Piscataqua River (6)	0.159
Great Bay (14)	0.078
Lower Piscataqua River (5)	0.063
Lower Piscataqua River (3)	0.044
Portsmouth Harbor (2)	0.034
Little Bay (13)	0.080
Little Bay (11)	0.071

Rochester WWTP	
Effluent Flow (MGD)=	3.9
Location	**% Effluent**
Salmon Falls River (10)	0.167
Upper Piscataqua River (9)	0.362
Upper Piscataqua River (8)	0.253
Upper Piscataqua River (6)	0.177
Great Bay (14)	0.072
Lower Piscataqua River (5)	0.056
Lower Piscataqua River (3)	0.039
Portsmouth Harbor (2)	0.030
Little Bay (13)	0.073
Little Bay (11)	0.065

Pease WWTP	
Effluent Flow (MGD)=	0.5
Location	**% Effluent**
Upper Piscataqua River (6)	0.006
Lower Piscataqua River (5)	0.007
Lower Piscataqua River (4)	0.007
Lower Piscataqua River (3)	0.006
Great Bay (14)	0.007
Portsmouth Harbor (2)	0.004
Portsmouth Harbor (1)	0.002
Portsmouth Harbor (7)	0.002
Little Bay (13)	0.007
Little Bay (11)	0.007

Portsmouth WWTP	
Effluent Flow (MGD)=	5.9
Location	**% Effluent**
Upper Piscataqua River (6)	0.038
Lower Piscataqua River (5)	0.045
Lower Piscataqua River (4)	0.043
Lower Piscataqua River (3)	0.042
Great Bay (14)	0.042
Portsmouth Harbor (2)	0.051
Portsmouth Harbor (1)	0.022
Portsmouth Harbor (7)	0.025
Little Bay (13)	0.044
Little Bay (11)	0.048

Table 4b. Computed % Effluent in the Great Bay Estuary System (Feb 2010 - Dec 2011) Design Effluent Flows

Dover WWTP	
Effluent Flow (MGD)=	4.7
Location	**% Effluent**
Salmon Falls River (10)	0.110
Upper Piscataqua River (9)	0.262
Upper Piscataqua River (8)	0.687
Upper Piscataqua River (6)	0.227
Great Bay (14)	0.111
Lower Piscataqua River (5)	0.089
Lower Piscataqua River (3)	0.063
Portsmouth Harbor (2)	0.048
Little Bay (13)	0.114
Little Bay (11)	0.102

Rochester WWTP	
Effluent Flow (MGD)=	5.0
Location	**% Effluent**
Salmon Falls River (10)	0.214
Upper Piscataqua River (9)	0.465
Upper Piscataqua River (8)	0.325
Upper Piscataqua River (6)	0.227
Great Bay (14)	0.092
Lower Piscataqua River (5)	0.072
Lower Piscataqua River (3)	0.050
Portsmouth Harbor (2)	0.038
Little Bay (13)	0.094
Little Bay (11)	0.083

Pease WWTP	
Effluent Flow (MGD)=	1.2
Location	**% Effluent**
Upper Piscataqua River (6)	0.015
Lower Piscataqua River (5)	0.016
Lower Piscataqua River (4)	0.017
Lower Piscataqua River (3)	0.013
Great Bay (14)	0.017
Portsmouth Harbor (2)	0.011
Portsmouth Harbor (1)	0.006
Portsmouth Harbor (7)	0.006
Little Bay (13)	0.018
Little Bay (11)	0.018

Portsmouth WWTP	
Effluent Flow (MGD)=	6.13
Location	**% Effluent**
Upper Piscataqua River (6)	0.039
Lower Piscataqua River (5)	0.047
Lower Piscataqua River (4)	0.045
Lower Piscataqua River (3)	0.044
Great Bay (14)	0.043
Portsmouth Harbor (2)	0.053
Portsmouth Harbor (1)	0.023
Portsmouth Harbor (7)	0.026
Little Bay (13)	0.046
Little Bay (11)	0.049

Table 5a. Computed Incremental Total Nitrogen (TN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011).
Dover WWTP - Current Effluent Flows

Dover WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	3.3	3.3	3.3
Monthly Effluent TN (mg/L)=	8	3	-
Long Term Effluent TN (mg/L)=	6	3	22
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Salmon Falls River (10)	0.00439	0.00208	0.01672
Upper Piscataqua River (9)	0.01050	0.00497	0.03997
Upper Piscataqua River (8)	0.02749	0.01302	0.10466
Upper Piscataqua River (6)	0.00908	0.00430	0.03457
Great Bay (14)	0.00445	0.00211	0.01695
Lower Piscataqua River (5)	0.00357	0.00169	0.01361
Lower Piscataqua River (3)	0.00253	0.00120	0.00965
Portsmouth Harbor (2)	0.00193	0.00091	0.00734
Little Bay (13)	0.00455	0.00215	0.01731
Little Bay (11)	0.00407	0.00193	0.01548

* A background TN of 0.3 mg/L was assumed.

Table 5b. Computed Incremental Total Nitrogen (TN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011).
Dover WWTP - Design Effluent Flows

Dover WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	4.7	4.7	4.7
Monthly Effluent TN (mg/L)=	8	3	-
Long Term Effluent TN (mg/L)=	6	3	22
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Salmon Falls River (10)	0.00626	0.00296	0.02382
Upper Piscataqua River (9)	0.01495	0.00708	0.05693
Upper Piscataqua River (8)	0.03916	0.01855	0.14906
Upper Piscataqua River (6)	0.01293	0.00613	0.04924
Great Bay (14)	0.00634	0.00300	0.02415
Lower Piscataqua River (5)	0.00509	0.00241	0.01938
Lower Piscataqua River (3)	0.00361	0.00171	0.01374
Portsmouth Harbor (2)	0.00275	0.00130	0.01045
Little Bay (13)	0.00648	0.00307	0.02466
Little Bay (11)	0.00579	0.00274	0.02205

* A background TN of 0.3 mg/L was assumed.

Table 6a. Computed Incremental Total Nitrogen (TN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Rochester WWTP - Current Effluent Flows

Rochester WWTP	**TN=8**	**TN=3**	**Current**
Effluent Flow (MGD)=	**3.9**	**3.9**	**3.9**
Monthly Effluent TN (mg/L)=	**8**	**3**	**-**
Long Term Effluent TN (mg/L)=	**6**	**3**	**35**
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Salmon Falls River (10)	0.00952	0.00451	0.05797
Upper Piscataqua River (9)	0.02066	0.00978	0.12574
Upper Piscataqua River (8)	0.01444	0.00684	0.08791
Upper Piscataqua River (6)	0.01007	0.00477	0.06133
Great Bay (14)	0.00411	0.00195	0.02504
Lower Piscataqua River (5)	0.00321	0.00152	0.01952
Lower Piscataqua River (3)	0.00223	0.00106	0.01358
Portsmouth Harbor (2)	0.00169	0.00080	0.01031
Little Bay (13)	0.00418	0.00198	0.02543
Little Bay (11)	0.00369	0.00175	0.02245

* A background TN of 0.3 mg/L was assumed.

Table 6b. Computed Incremental Total Nitrogen (TN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Rochester WWTP - Design Effluent Flows

Rochester WWTP	**TN=8**	**TN=3**	**Current**
Effluent Flow (MGD)=	**5.0**	**5.0**	**5.0**
Monthly Effluent TN (mg/L)=	**8**	**3**	**-**
Long Term Effluent TN (mg/L)=	**6**	**3**	**35**
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Salmon Falls River (10)	0.01221	0.00578	0.07432
Upper Piscataqua River (9)	0.02648	0.01254	0.16121
Upper Piscataqua River (8)	0.01851	0.00877	0.11270
Upper Piscataqua River (6)	0.01292	0.00612	0.07863
Great Bay (14)	0.00527	0.00250	0.03210
Lower Piscataqua River (5)	0.00411	0.00195	0.02503
Lower Piscataqua River (3)	0.00286	0.00135	0.01741
Portsmouth Harbor (2)	0.00217	0.00103	0.01322
Little Bay (13)	0.00536	0.00254	0.03260
Little Bay (11)	0.00473	0.00224	0.02878

* A background TN of 0.3 mg/L was assumed.

Table 7a. Computed Incremental Total Nitrogen (TN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Pease WWTP - Current Effluent Flows

Pease WWTP	**TN=8**	**TN=3**	**Current**
Effluent Flow (MGD)=	**0.5**	**0.5**	**0.5**
Monthly Effluent TN (mg/L)=	**8**	**3**	**-**
Long Term Effluent TN (mg/L)=	**6**	**3**	**9**
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Upper Piscataqua River (6)	0.00035	0.00017	0.00054
Lower Piscataqua River (5)	0.00039	0.00019	0.00060
Lower Piscataqua River (4)	0.00041	0.00019	0.00062
Lower Piscataqua River (3)	0.00032	0.00015	0.00048
Great Bay (14)	0.00040	0.00019	0.00061
Portsmouth Harbor (2)	0.00025	0.00012	0.00038
Portsmouth Harbor (1)	0.00013	0.00006	0.00020
Portsmouth Harbor (7)	0.00014	0.00007	0.00022
Little Bay (13)	0.00042	0.00020	0.00064
Little Bay (11)	0.00042	0.00020	0.00064

* A background TN of 0.3 mg/L was assumed.

Table 7b. Computed Incremental Total Nitrogen (TN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Pease WWTP - Design Effluent Flows

Pease WWTP	**TN=8**	**TN=3**	**Current**
Effluent Flow (MGD)=	**1.2**	**1.2**	**1.2**
Monthly Effluent TN (mg/L)=	**8**	**3**	**-**
Long Term Effluent TN (mg/L)=	**6**	**3**	**9**
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Upper Piscataqua River (6)	0.00084	0.00040	0.00129
Lower Piscataqua River (5)	0.00094	0.00045	0.00143
Lower Piscataqua River (4)	0.00098	0.00046	0.00149
Lower Piscataqua River (3)	0.00076	0.00036	0.00116
Great Bay (14)	0.00096	0.00046	0.00147
Portsmouth Harbor (2)	0.00060	0.00028	0.00091
Portsmouth Harbor (1)	0.00032	0.00015	0.00049
Portsmouth Harbor (7)	0.00034	0.00016	0.00052
Little Bay (13)	0.00101	0.00048	0.00155
Little Bay (11)	0.00100	0.00048	0.00153

* A background TN of 0.3 mg/L was assumed.

Table 8a. Computed Incremental Total Nitrogen (TN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Portsmouth WWTP - Current Effluent Flows

Portsmouth WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	5.9	5.9	5.9
Monthly Effluent TN (mg/L)=	8	3	-
Long Term Effluent TN (mg/L)=	6	3	13
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Upper Piscataqua River (6)	0.00215	0.00102	0.00479
Lower Piscataqua River (5)	0.00257	0.00122	0.00573
Lower Piscataqua River (4)	0.00247	0.00117	0.00551
Lower Piscataqua River (3)	0.00242	0.00115	0.00540
Great Bay (14)	0.00237	0.00112	0.00527
Portsmouth Harbor (2)	0.00292	0.00139	0.00652
Portsmouth Harbor (1)	0.00124	0.00059	0.00276
Portsmouth Harbor (7)	0.00141	0.00067	0.00314
Little Bay (13)	0.00250	0.00119	0.00558
Little Bay (11)	0.00271	0.00128	0.00603

* A background TN of 0.3 mg/L was assumed.

Table 8b. Computed Incremental Total Nitrogen (TN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Portsmouth WWTP - Design Effluent Flows

Portsmouth WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	6.13	6.13	6.13
Monthly Effluent TN (mg/L)=	8	3	-
Long Term Effluent TN (mg/L)=	6	3	13
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Upper Piscataqua River (6)	0.00224	0.00106	0.00498
Lower Piscataqua River (5)	0.00267	0.00126	0.00595
Lower Piscataqua River (4)	0.00257	0.00122	0.00573
Lower Piscataqua River (3)	0.00252	0.00119	0.00561
Great Bay (14)	0.00246	0.00117	0.00548
Portsmouth Harbor (2)	0.00304	0.00144	0.00677
Portsmouth Harbor (1)	0.00129	0.00061	0.00287
Portsmouth Harbor (7)	0.00146	0.00069	0.00326
Little Bay (13)	0.00260	0.00123	0.00580
Little Bay (11)	0.00281	0.00133	0.00627

* A background TN of 0.3 mg/L was assumed.

Table 9a. Computed Incremental Dissolved Inorganic Nitrogen (DIN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Dover WWTP - Current Effluent Flows

Dover WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	3.3	3.3	3.3
Long Term Effluent TN (mg/L)=	6	3	22
Long Term Effluent DIN (mg/L)=	3	1	18
Location	**delta DIN (mg/L)**	**delta DIN (mg/L)**	**delta DIN (mg/L)**
Salmon Falls River (10)	0.00224	0.00069	0.01380
Upper Piscataqua River (9)	0.00534	0.00166	0.03297
Upper Piscataqua River (8)	0.01399	0.00434	0.08633
Upper Piscataqua River (6)	0.00462	0.00143	0.02852
Great Bay (14)	0.00227	0.00070	0.01398
Lower Piscataqua River (5)	0.00182	0.00056	0.01122
Lower Piscataqua River (3)	0.00129	0.00040	0.00796
Portsmouth Harbor (2)	0.00098	0.00030	0.00605
Little Bay (13)	0.00231	0.00072	0.01428
Little Bay (11)	0.00207	0.00064	0.01277

* A background DIN of 0.1 mg/L was assumed.

Table 9b. Computed Incremental Dissolved Inorganic Nitrogen (DIN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Dover WWTP - Design Effluent Flows

Dover WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	4.7	4.7	4.7
Long Term Effluent TN (mg/L)=	6	3	22
Long Term Effluent DIN (mg/L)=	3	1	18
Location	**delta DIN (mg/L)**	**delta DIN (mg/L)**	**delta DIN (mg/L)**
Salmon Falls River (10)	0.00318	0.00099	0.01965
Upper Piscataqua River (9)	0.00761	0.00236	0.04696
Upper Piscataqua River (8)	0.01992	0.00618	0.12296
Upper Piscataqua River (6)	0.00658	0.00204	0.04061
Great Bay (14)	0.00323	0.00100	0.01992
Lower Piscataqua River (5)	0.00259	0.00080	0.01598
Lower Piscataqua River (3)	0.00184	0.00057	0.01134
Portsmouth Harbor (2)	0.00140	0.00043	0.00862
Little Bay (13)	0.00330	0.00102	0.02034
Little Bay (11)	0.00295	0.00091	0.01819

* A background DIN of 0.1 mg/L was assumed.

Table 10a. Computed Incremental Dissolved Inorganic Nitrogen (DIN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Rochester WWTP - Current Effluent Flows

Rochester WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	3.9	3.9	3.9
Long Term Effluent TN (mg/L)=	6	3	35
Long Term Effluent DIN (mg/L)=	5.5	2.5	34.5
Location	**delta DIN (mg/L)**	**delta DIN (mg/L)**	**delta DIN (mg/L)**
Salmon Falls River (10)	0.00902	0.00401	0.05747
Upper Piscataqua River (9)	0.01957	0.00870	0.12466
Upper Piscataqua River (8)	0.01368	0.00608	0.08715
Upper Piscataqua River (6)	0.00954	0.00424	0.06080
Great Bay (14)	0.00390	0.00173	0.02482
Lower Piscataqua River (5)	0.00304	0.00135	0.01936
Lower Piscataqua River (3)	0.00211	0.00094	0.01346
Portsmouth Harbor (2)	0.00160	0.00071	0.01022
Little Bay (13)	0.00396	0.00176	0.02521
Little Bay (11)	0.00349	0.00155	0.02225

* A background DIN of 0.1 mg/L was assumed.

Table 10b. Computed Incremental Dissolved Inorganic Nitrogen (DIN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011). Rochester WWTP - Design Effluent Flows

Rochester WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	5.0	5.0	5.0
Long Term Effluent TN (mg/L)=	6	3	35
Long Term Effluent DIN (mg/L)=	5.5	2.5	34.5
Location	**delta DIN (mg/L)**	**delta DIN (mg/L)**	**delta DIN (mg/L)**
Salmon Falls River (10)	0.01157	0.00514	0.07368
Upper Piscataqua River (9)	0.02509	0.01115	0.15982
Upper Piscataqua River (8)	0.01754	0.00779	0.11173
Upper Piscataqua River (6)	0.01224	0.00544	0.07795
Great Bay (14)	0.00499	0.00222	0.03182
Lower Piscataqua River (5)	0.00390	0.00173	0.02481
Lower Piscataqua River (3)	0.00271	0.00120	0.01726
Portsmouth Harbor (2)	0.00206	0.00091	0.01310
Little Bay (13)	0.00507	0.00225	0.03232
Little Bay (11)	0.00448	0.00199	0.02853

* A background DIN of 0.1 mg/L was assumed.

Table 11a. Computed Incremental Dissolved Inorganic Nitrogen (DIN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011).
Pease WWTP - Current Effluent Flows

Pease WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	0.5	0.5	0.5
Long Term Effluent TN (mg/L)=	6	3	9
Long Term Effluent DIN (mg/L)=	3	1	6
Location	delta DIN (mg/L)	delta DIN (mg/L)	delta DIN (mg/L)
Upper Piscataqua River (6)	0.00018	0.00006	0.00036
Lower Piscataqua River (5)	0.00020	0.00006	0.00041
Lower Piscataqua River (4)	0.00021	0.00006	0.00042
Lower Piscataqua River (3)	0.00016	0.00005	0.00033
Great Bay (14)	0.00020	0.00006	0.00042
Portsmouth Harbor (2)	0.00013	0.00004	0.00026
Portsmouth Harbor (1)	0.00007	0.00002	0.00014
Portsmouth Harbor (7)	0.00007	0.00002	0.00015
Little Bay (13)	0.00021	0.00007	0.00044
Little Bay (11)	0.00021	0.00007	0.00043

* A background DIN of 0.1 mg/L was assumed.

Table 11b. Computed Incremental Dissolved Inorganic Nitrogen (DIN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011).
Pease WWTP - Design Effluent Flows

Pease WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	1.2	1.2	1.2
Long Term Effluent TN (mg/L)=	6	3	9
Long Term Effluent DIN (mg/L)=	3	1	6
Location	delta DIN (mg/L)	delta DIN (mg/L)	delta DIN (mg/L)
Upper Piscataqua River (6)	0.00043	0.00013	0.00087
Lower Piscataqua River (5)	0.00048	0.00015	0.00097
Lower Piscataqua River (4)	0.00050	0.00015	0.00101
Lower Piscataqua River (3)	0.00039	0.00012	0.00079
Great Bay (14)	0.00049	0.00015	0.00100
Portsmouth Harbor (2)	0.00030	0.00009	0.00062
Portsmouth Harbor (1)	0.00016	0.00005	0.00033
Portsmouth Harbor (7)	0.00017	0.00005	0.00035
Little Bay (13)	0.00052	0.00016	0.00105
Little Bay (11)	0.00051	0.00016	0.00104

* A background DIN of 0.1 mg/L was assumed.

Table 12a. Computed Incremental Dissolved Inorganic Nitrogen (DIN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011).
Portsmouth WWTP - Current Effluent Flows

Portsmouth WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	**5.9**	**5.9**	**5.9**
Long Term Effluent TN (mg/L)=	**6**	**3**	**13**
Long Term Effluent DIN (mg/L)=	**3**	**1**	**10**
Location	**delta DIN (mg/L)**	**delta DIN (mg/L)**	**delta DIN (mg/L)**
Upper Piscataqua River (6)	0.00109	0.00034	0.00374
Lower Piscataqua River (5)	0.00131	0.00041	0.00446
Lower Piscataqua River (4)	0.00126	0.00039	0.00430
Lower Piscataqua River (3)	0.00123	0.00038	0.00421
Great Bay (14)	0.00120	0.00037	0.00411
Portsmouth Harbor (2)	0.00149	0.00046	0.00508
Portsmouth Harbor (1)	0.00063	0.00020	0.00215
Portsmouth Harbor (7)	0.00072	0.00022	0.00245
Little Bay (13)	0.00127	0.00040	0.00435
Little Bay (11)	0.00138	0.00043	0.00470

* A background DIN of 0.1 mg/L was assumed.

Table 12b. Computed Incremental Dissolved Inorganic Nitrogen (DIN)* in the Great Bay Estuary System (Feb 2010 - Dec 2011).
Portsmouth WWTP - Design Effluent Flows

Portsmouth WWTP	TN=8	TN=3	Current
Effluent Flow (MGD)=	**6.13**	**6.13**	**6.13**
Long Term Effluent TN (mg/L)=	**6**	**3**	**13**
Long Term Effluent DIN (mg/L)=	**3**	**1**	**10**
Location	**delta DIN (mg/L)**	**delta DIN (mg/L)**	**delta DIN (mg/L)**
Upper Piscataqua River (6)	0.00114	0.00035	0.00388
Lower Piscataqua River (5)	0.00136	0.00042	0.00464
Lower Piscataqua River (4)	0.00131	0.00041	0.00446
Lower Piscataqua River (3)	0.00128	0.00040	0.00437
Great Bay (14)	0.00125	0.00039	0.00427
Portsmouth Harbor (2)	0.00155	0.00048	0.00528
Portsmouth Harbor (1)	0.00066	0.00020	0.00224
Portsmouth Harbor (7)	0.00074	0.00023	0.00254
Little Bay (13)	0.00132	0.00041	0.00452
Little Bay (11)	0.00143	0.00044	0.00489

* A background DIN of 0.1 mg/L was assumed.

Table 13a. Incremental TN* in the GBES (Feb 2010 - Dec 2011).
All WWTPs** - Current Effluent Flows

	TN=8	TN=3	Current
Location	**delta TN (mg/L)**	**delta TN (mg/L)**	**delta TN (mg/L)**
Salmon Falls River (10)	0.01769	0.00838	0.08333
Upper Piscataqua River (9)	0.03727	0.01765	0.18025
Upper Piscataqua River (8)	0.04903	0.02323	0.20970
Upper Piscataqua River (6)	0.02675	0.01267	0.11444
Great Bay (14)	0.02346	0.01111	0.08082
Lower Piscataqua River (5)	0.01443	0.00684	0.05168
Lower Piscataqua River (3)	0.00926	0.00439	0.03432
Portsmouth Harbor (2)	0.00753	0.00357	0.02715
Little Bay (13)	0.02071	0.00981	0.07314
Little Bay (11)	0.01687	0.00799	0.06022

* A background TN of 0.3 mg/L was assumed.

** Dover, Rochester, Pease, Portsmouth, Exeter, Durham, and Newmarket WWTPs.

Table 13b. Incremental DIN* in the GBES (Feb 2010 - Dec 2011).
All WWTPs** - Current Effluent Flows

	TN=8	TN=3	Current
Location	**delta DIN (mg/L)**	**delta DIN (mg/L)**	**delta DIN (mg/L)**
Salmon Falls River (10)	0.01317	0.00530	0.07805
Upper Piscataqua River (9)	0.02802	0.01132	0.16916
Upper Piscataqua River (8)	0.03128	0.01154	0.18713
Upper Piscataqua River (6)	0.01803	0.00688	0.10412
Great Bay (14)	0.01374	0.00479	0.07032
Lower Piscataqua River (5)	0.00875	0.00312	0.04537
Lower Piscataqua River (3)	0.00569	0.00205	0.03030
Portsmouth Harbor (2)	0.00457	0.00163	0.02385
Little Bay (13)	0.01237	0.00437	0.06400
Little Bay (11)	0.01020	0.00363	0.05284

* A background DIN of 0.1 mg/L was assumed.

** Dover, Rochester, Pease, Portsmouth, Exeter, Durham, and Newmarket WWTPs.

FIGURES

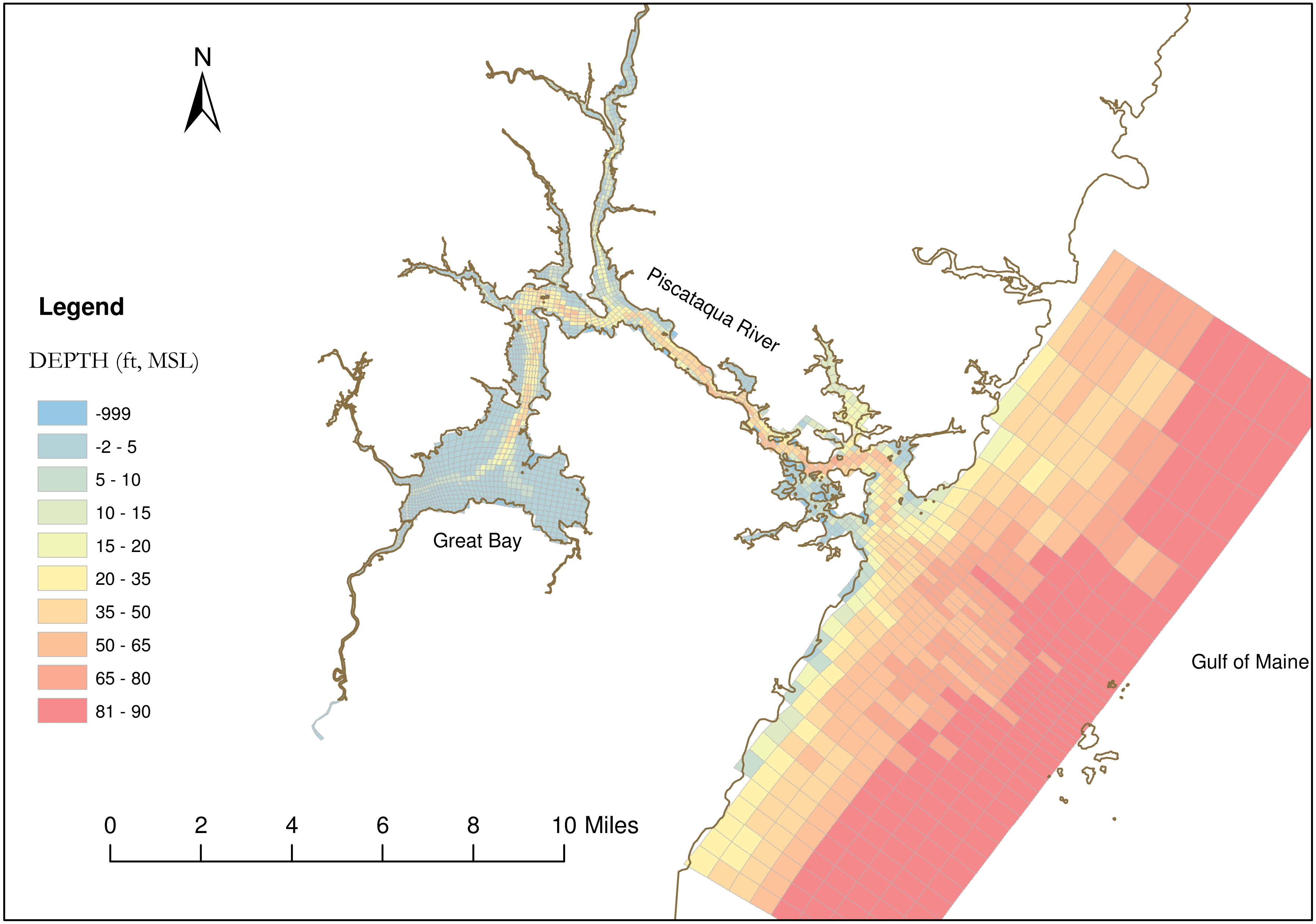

FIGURE 1. Map of Hydrodynamic Model Domain

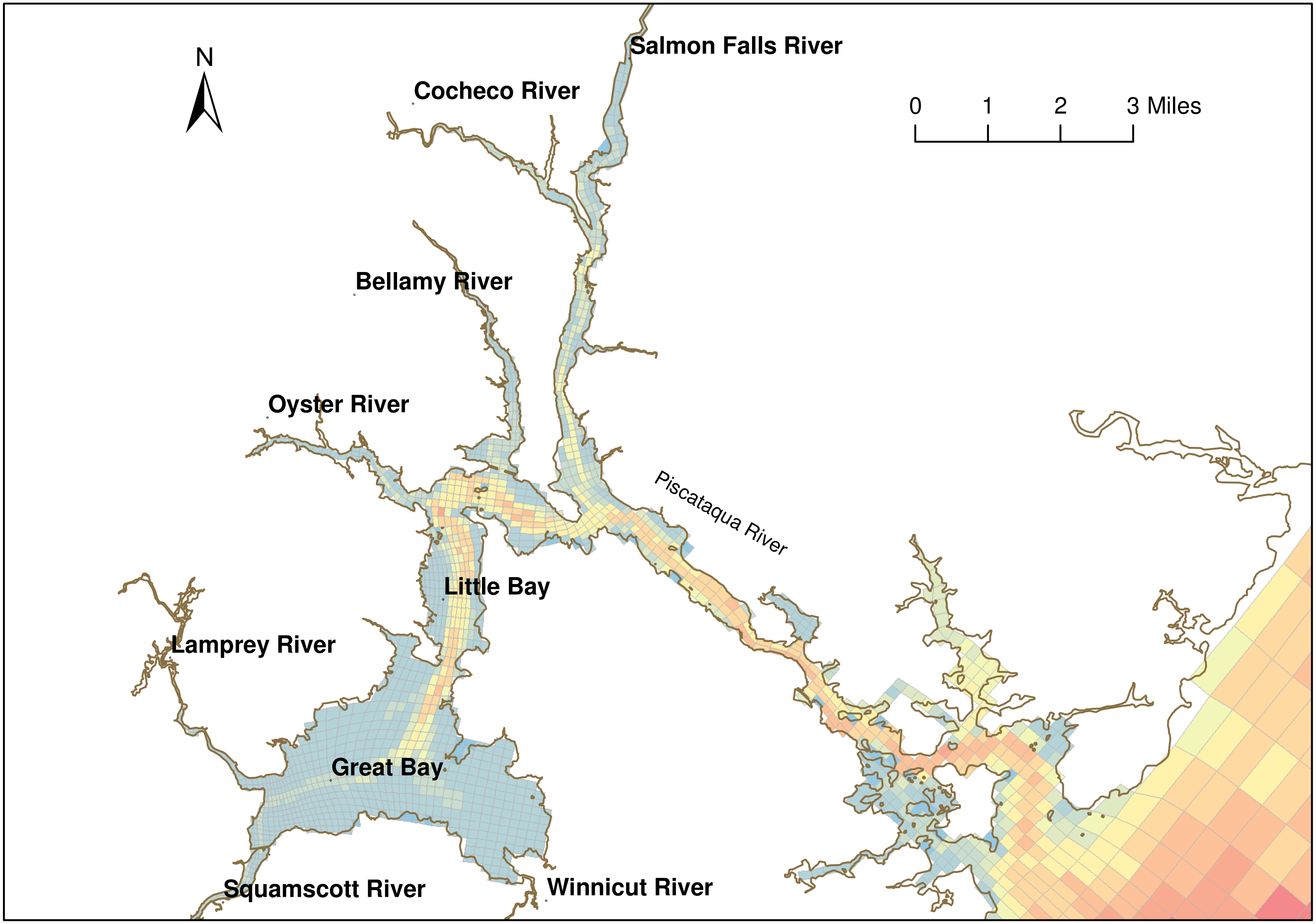

FIGURE 2. Zoom-In View of the Model Grid

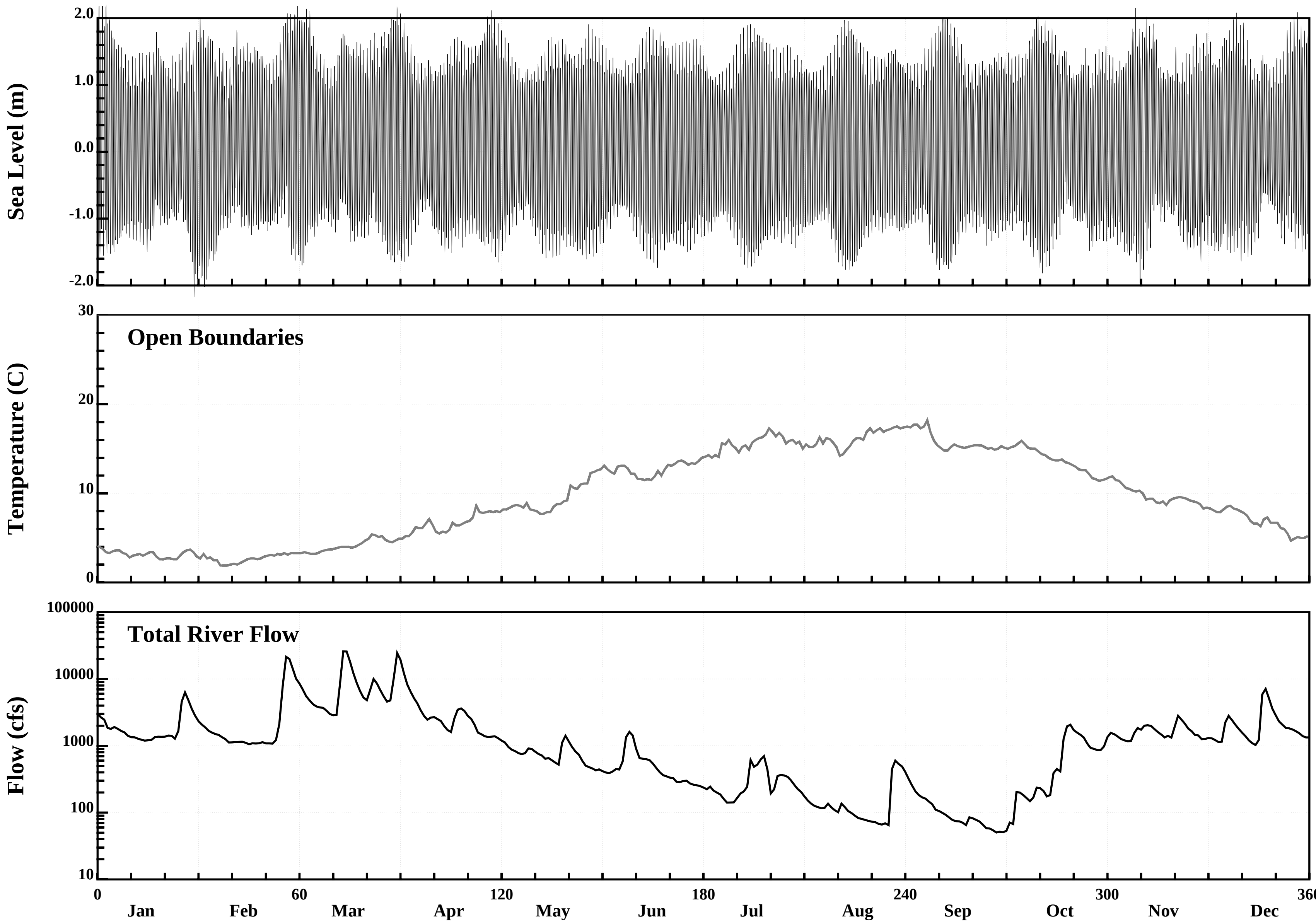

FIGURE 3. Model Boundary Forcing Data 2010

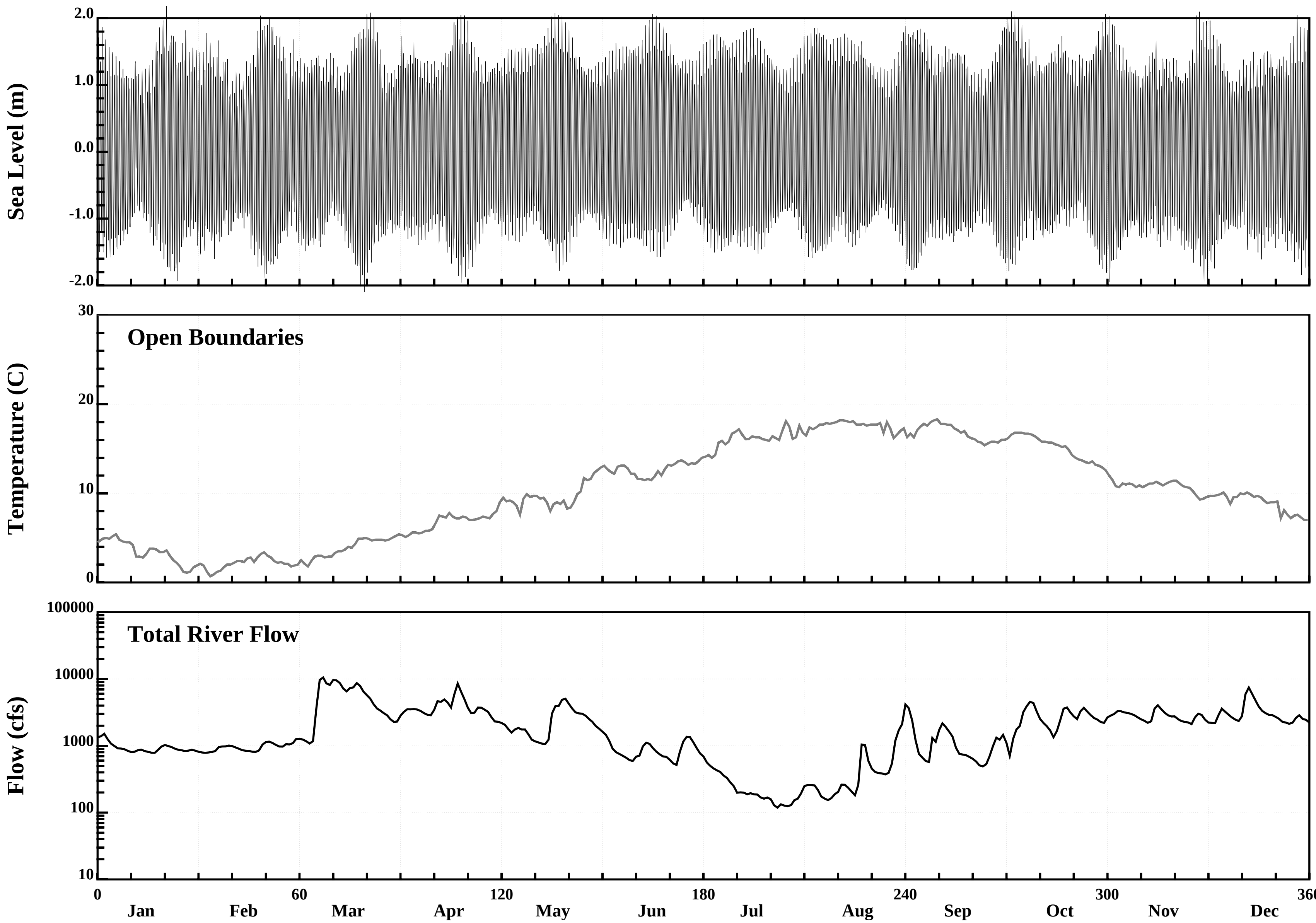

FIGURE 4. Model Boundary Forcing Data 2011

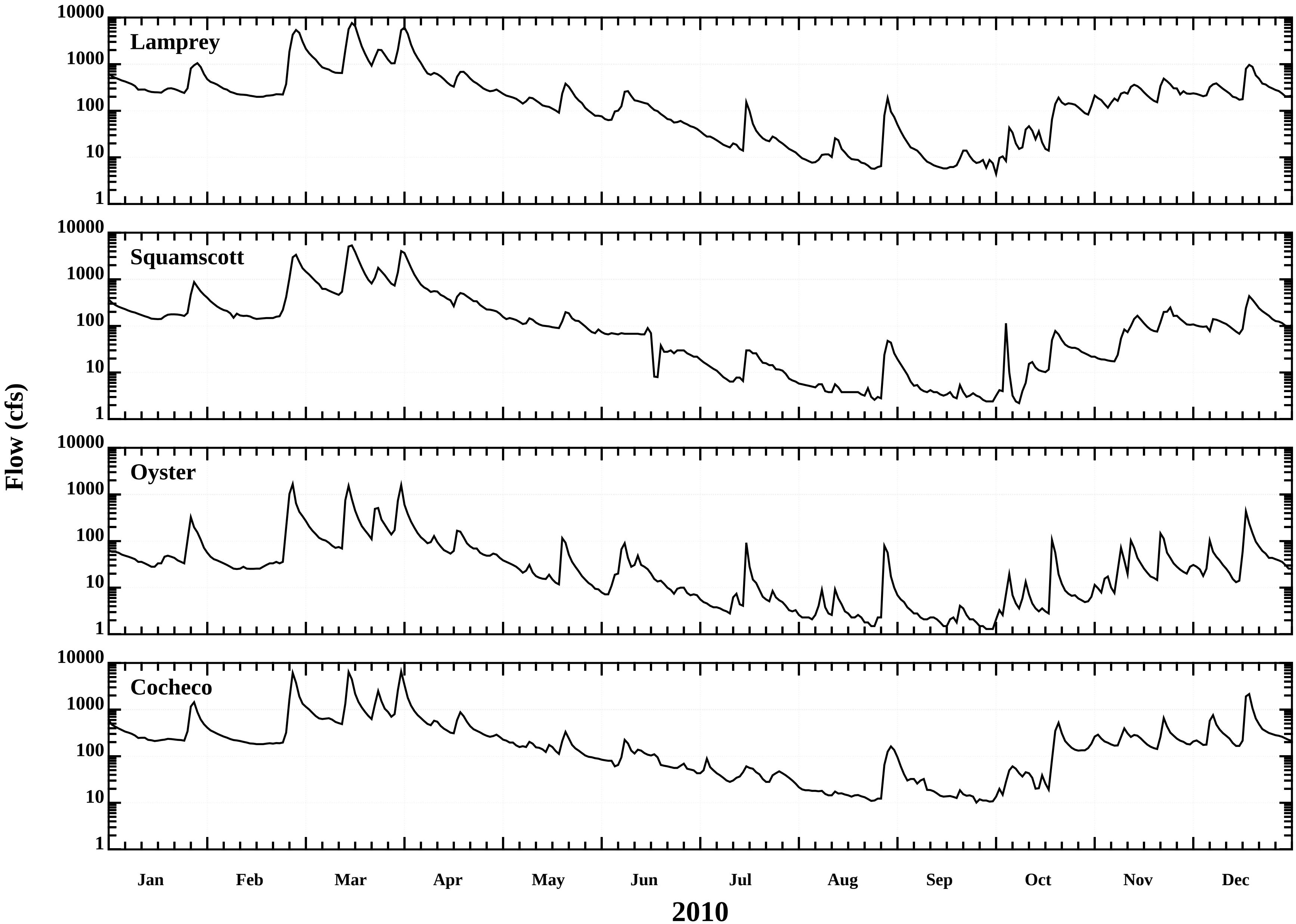

FIGURE 5. River Flows Used in Model Simulations : 2010

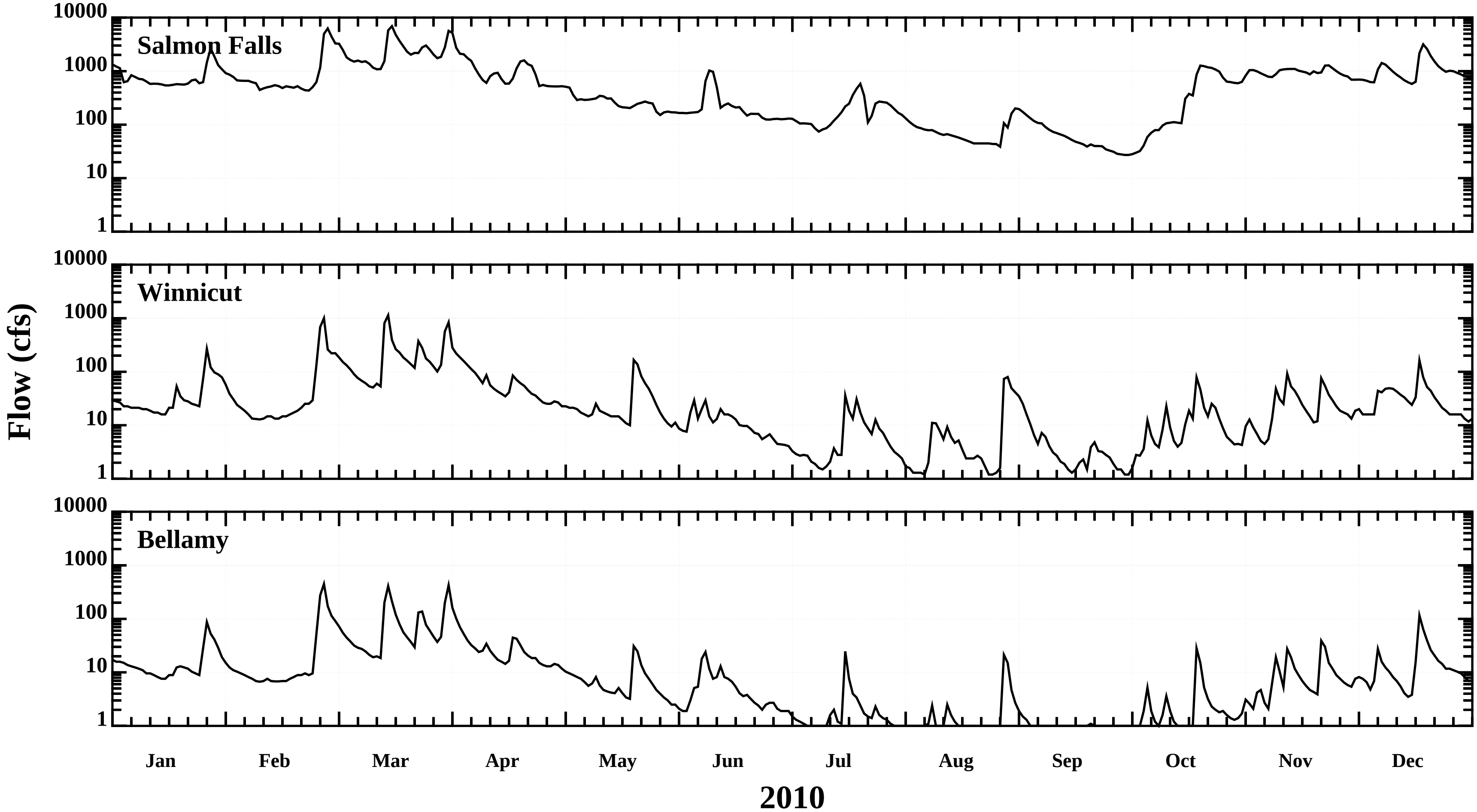

FIGURE 5. River Flows Used in Model Simulations : 2010 (Cont.)

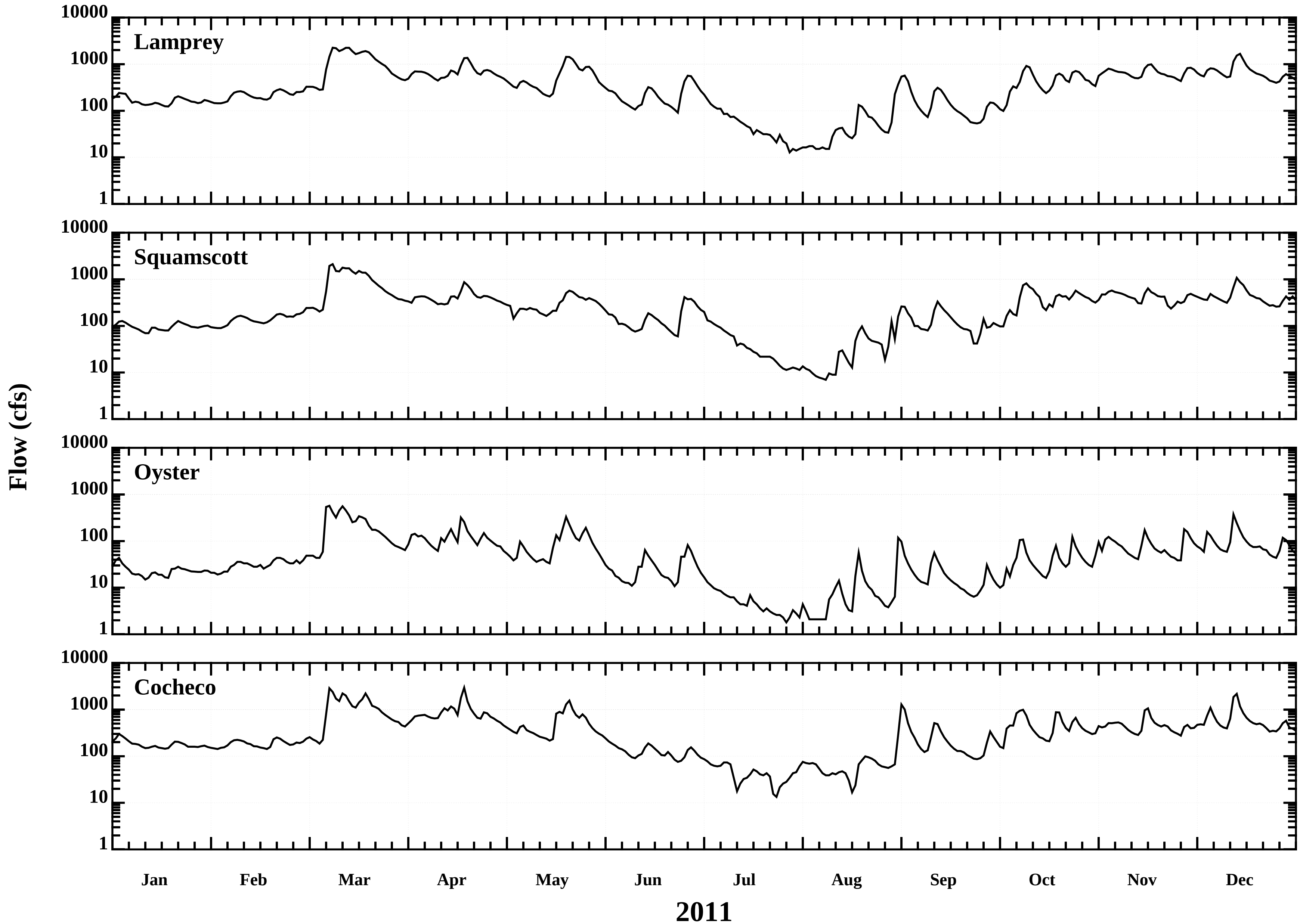

FIGURE 6. River Flows Used in Model Simulations : 2011

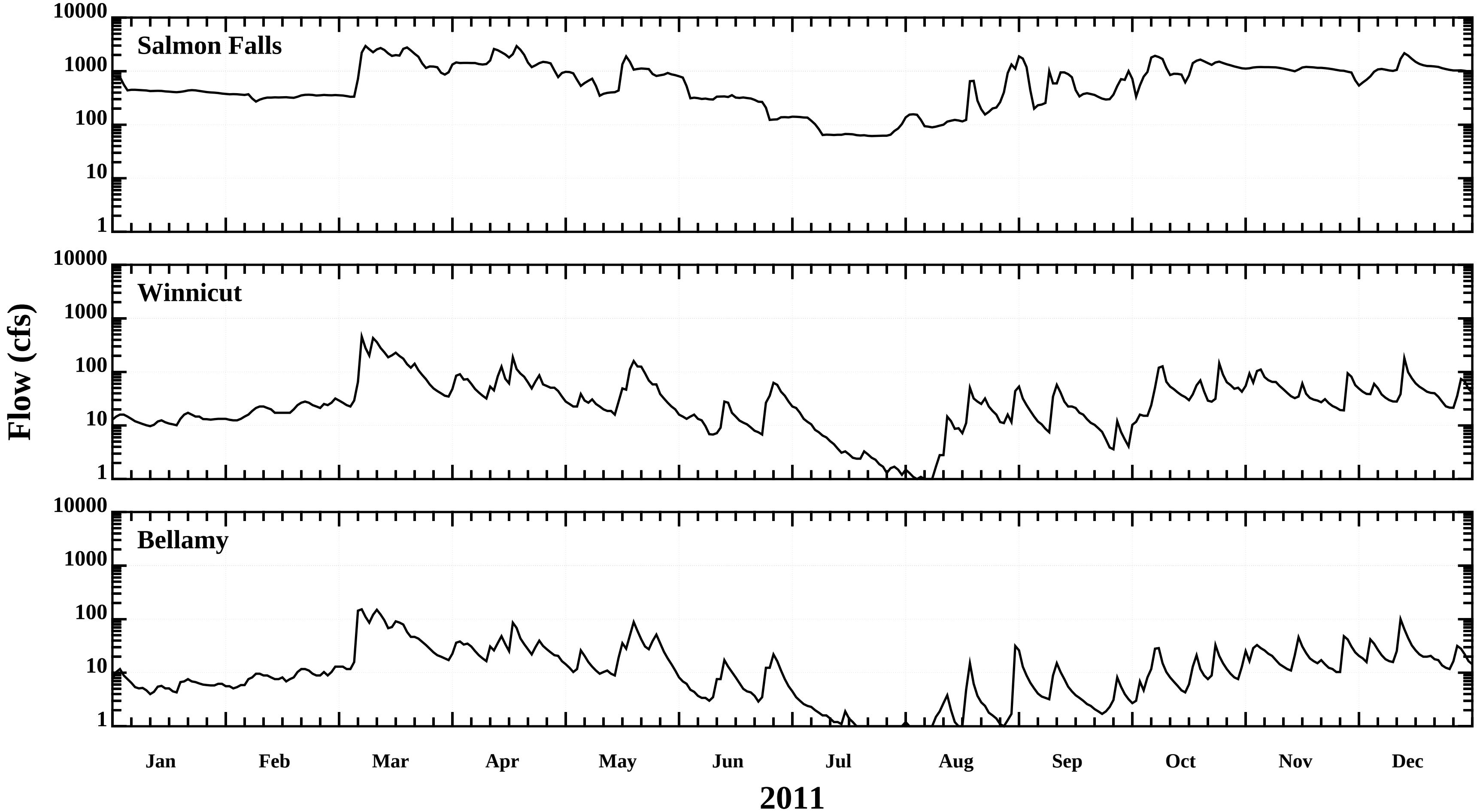

FIGURE 6. River Flows Used in Model Simulations : 2011 (Cont.)

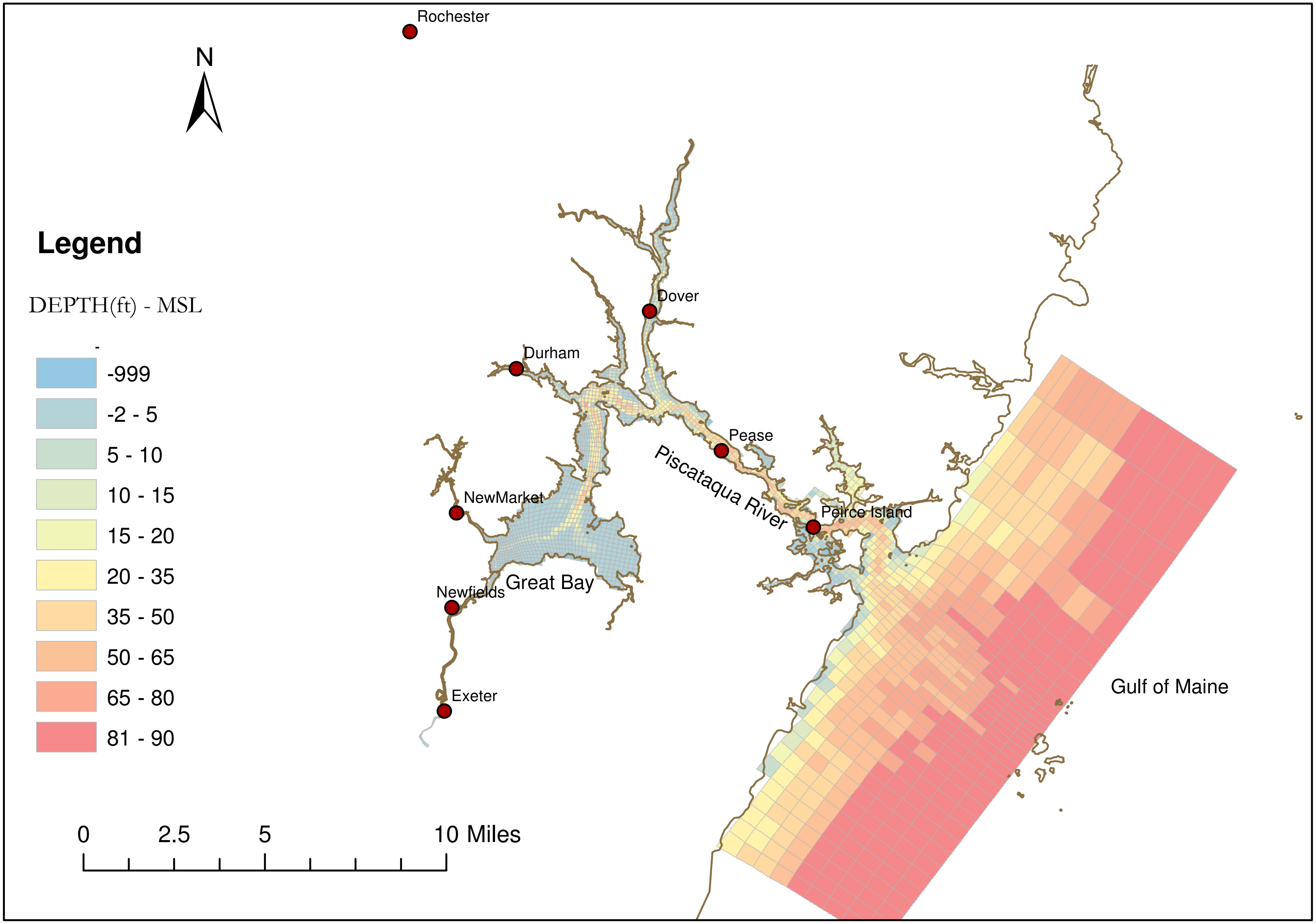

FIGURE 7. Location of Sewage Treatment Plants

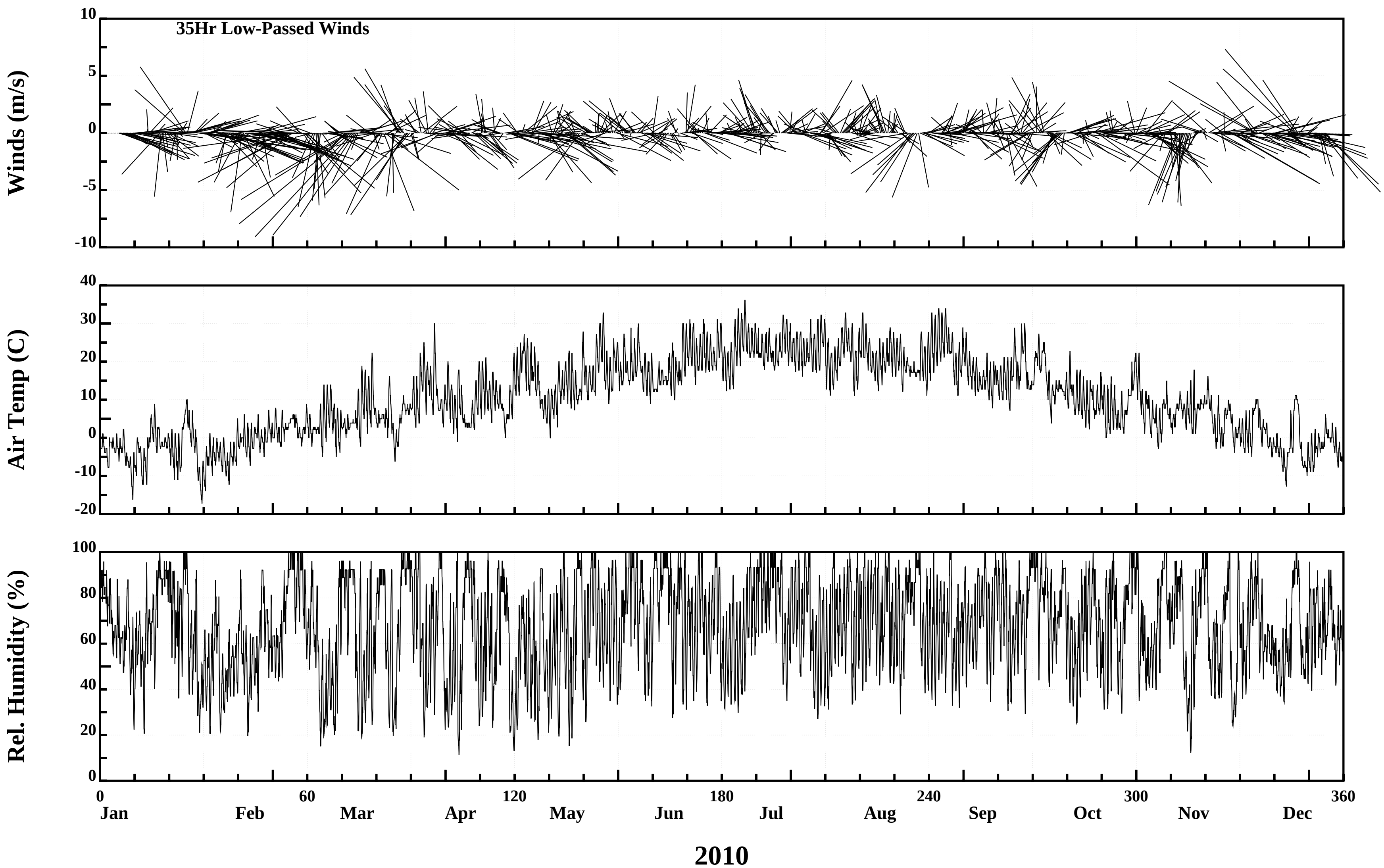

FIGURE 8. Meteorological Forcing Data: 2010

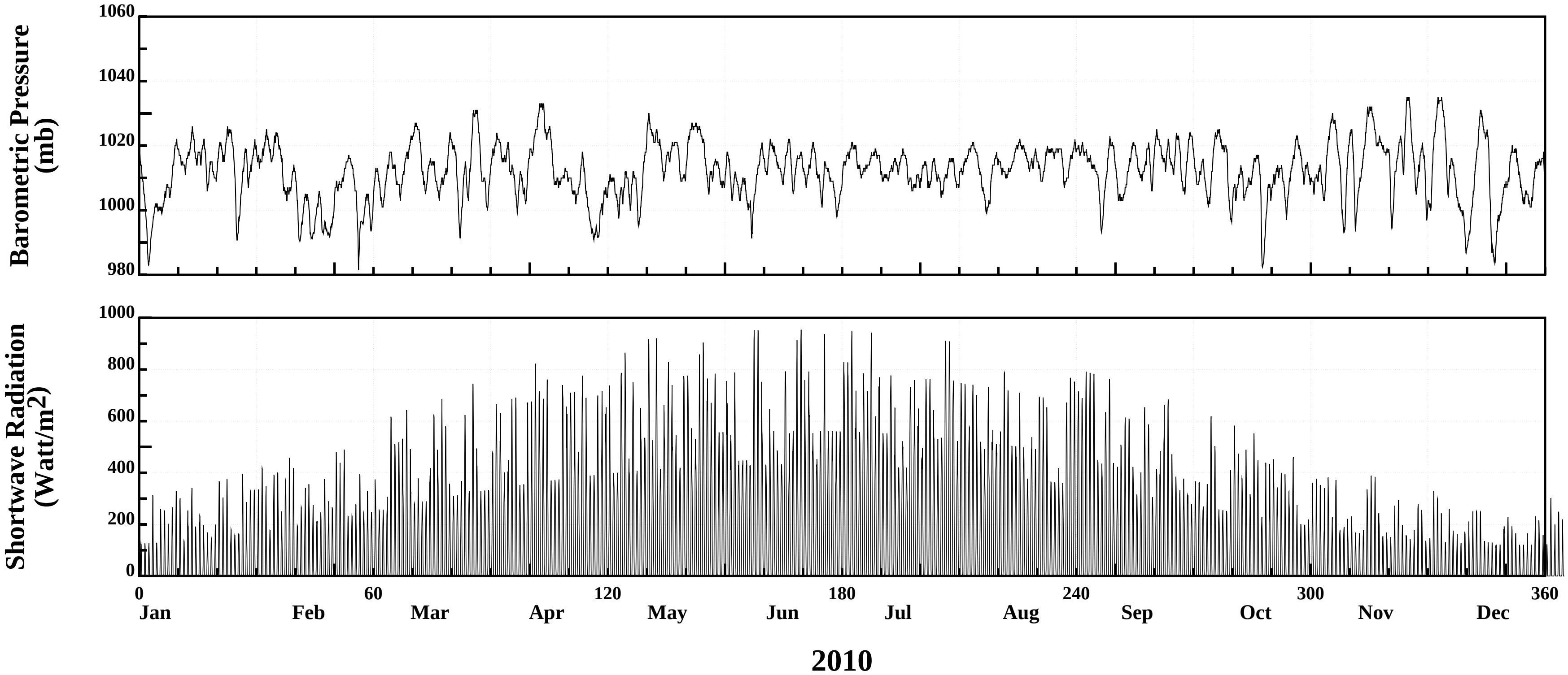

FIGURE 8. Meteorological Forcing Data: 2010 (Cont.)

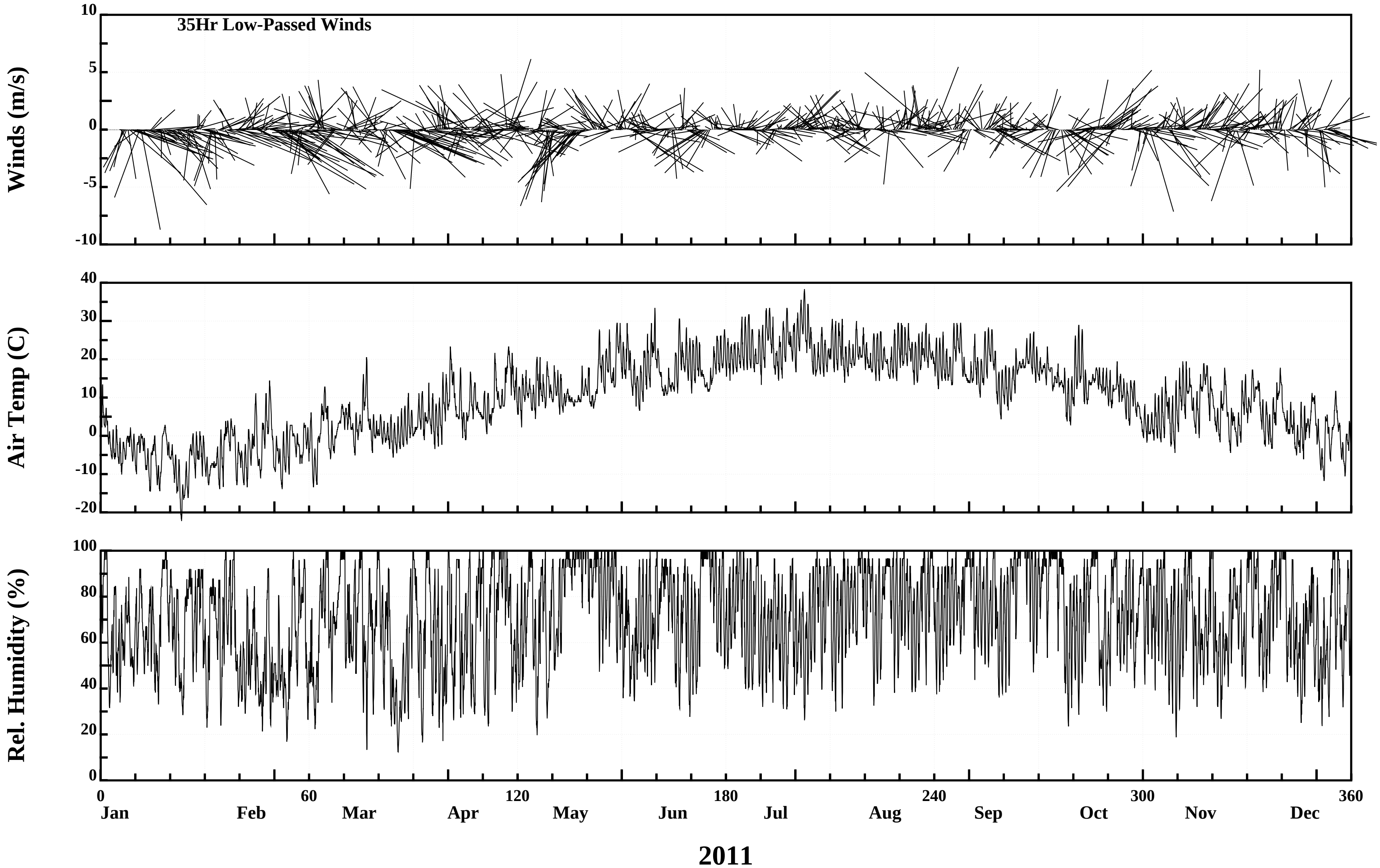

FIGURE 9. Meteorological Forcing Data: 2011

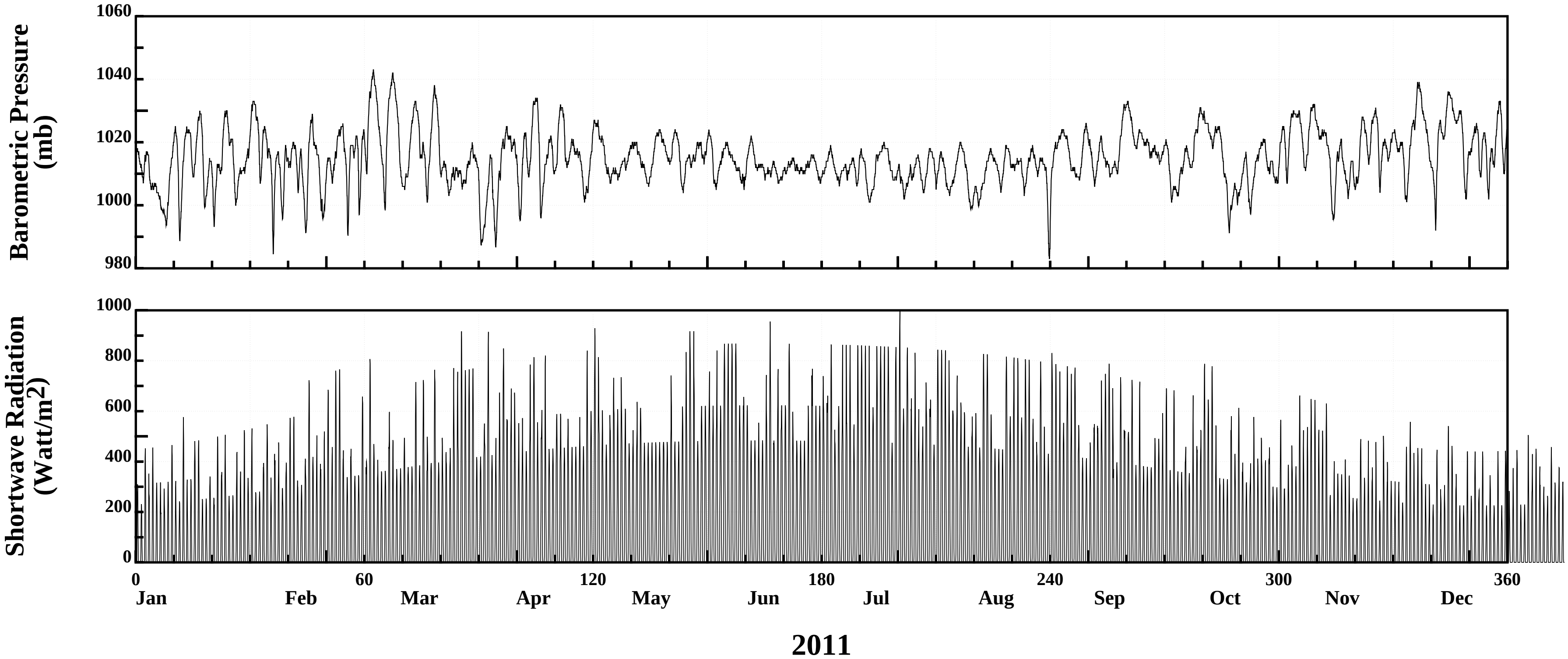

FIGURE 9. Meteorological Forcing Data: 2010 (Cont.)

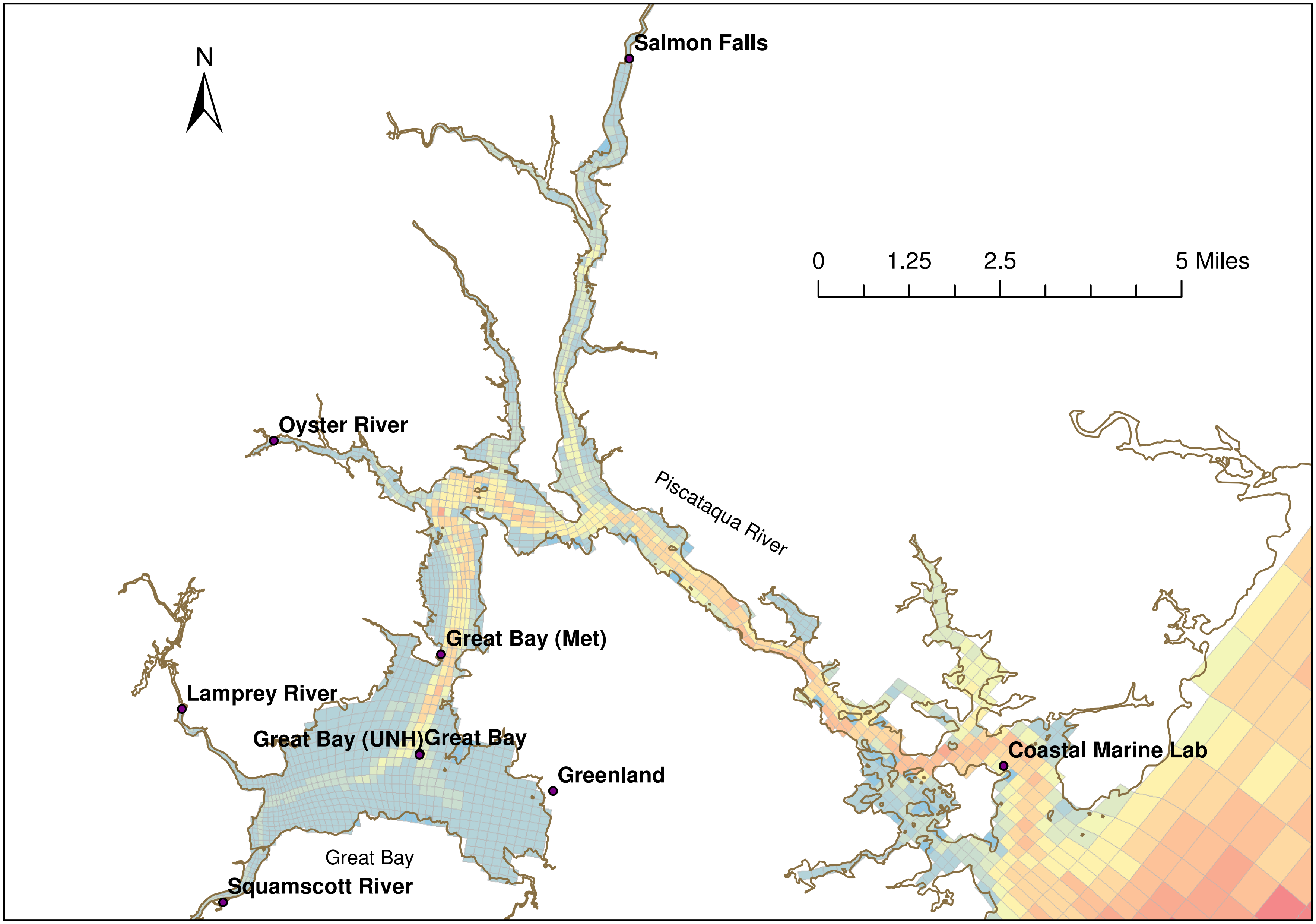

FIGURE 10. Location of Continuous Monitoring Stations

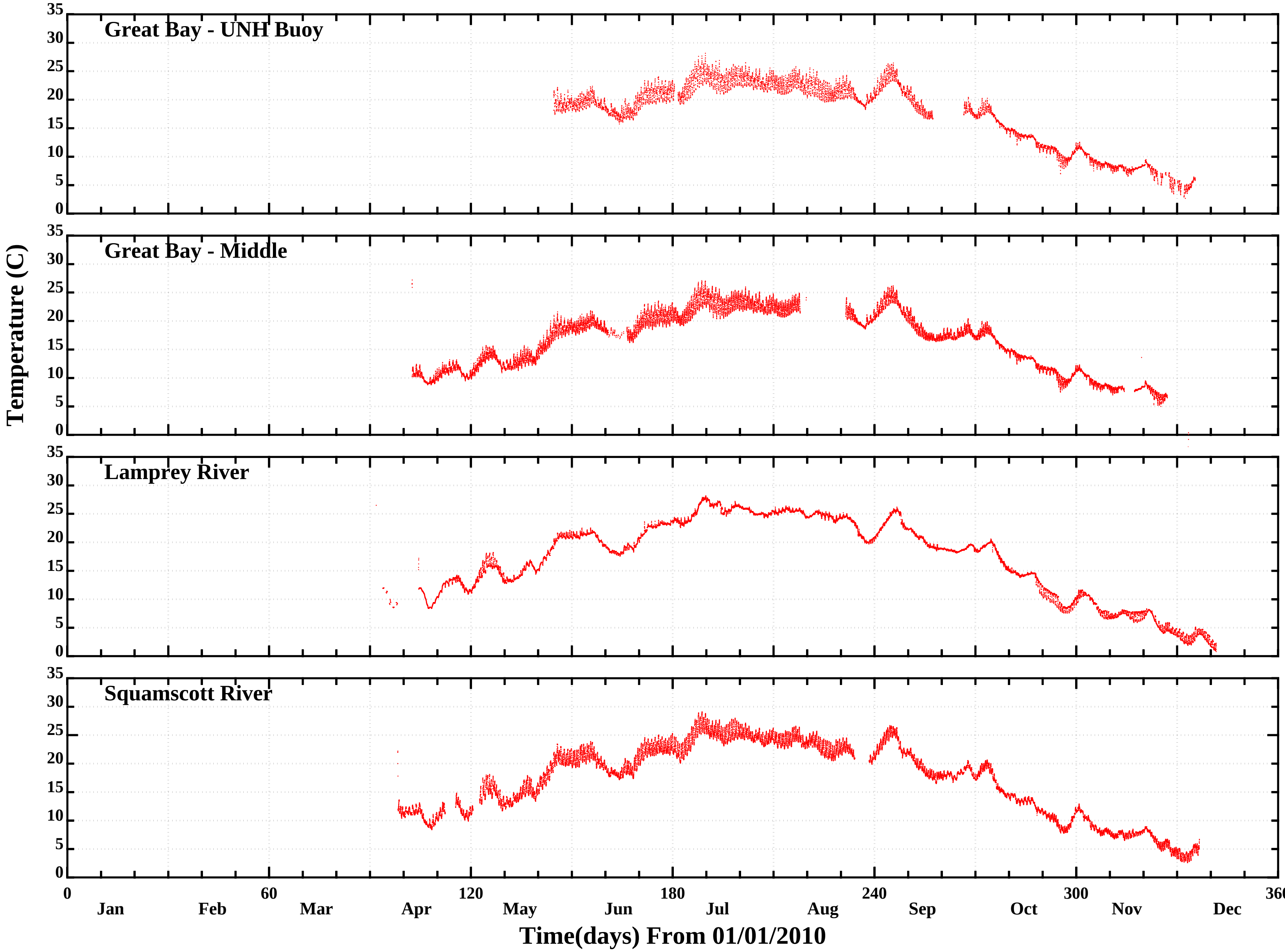

FIGURE 11. Observed Water Temperature Data at Monitoring Stations: 2010

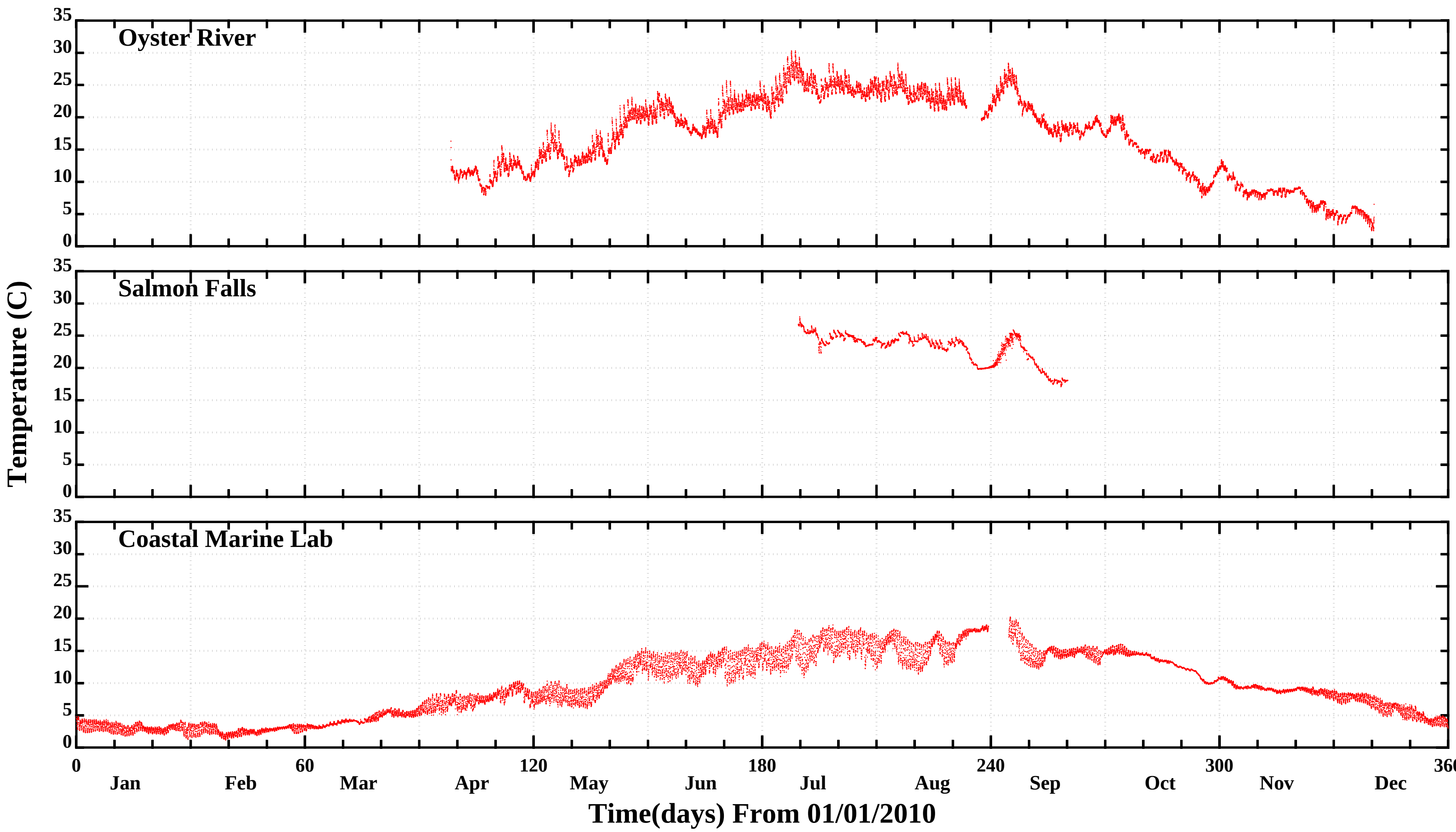

FIGURE 11. Observed Water Temperature Data at Monitoring Stations: 2010 (Cont.)

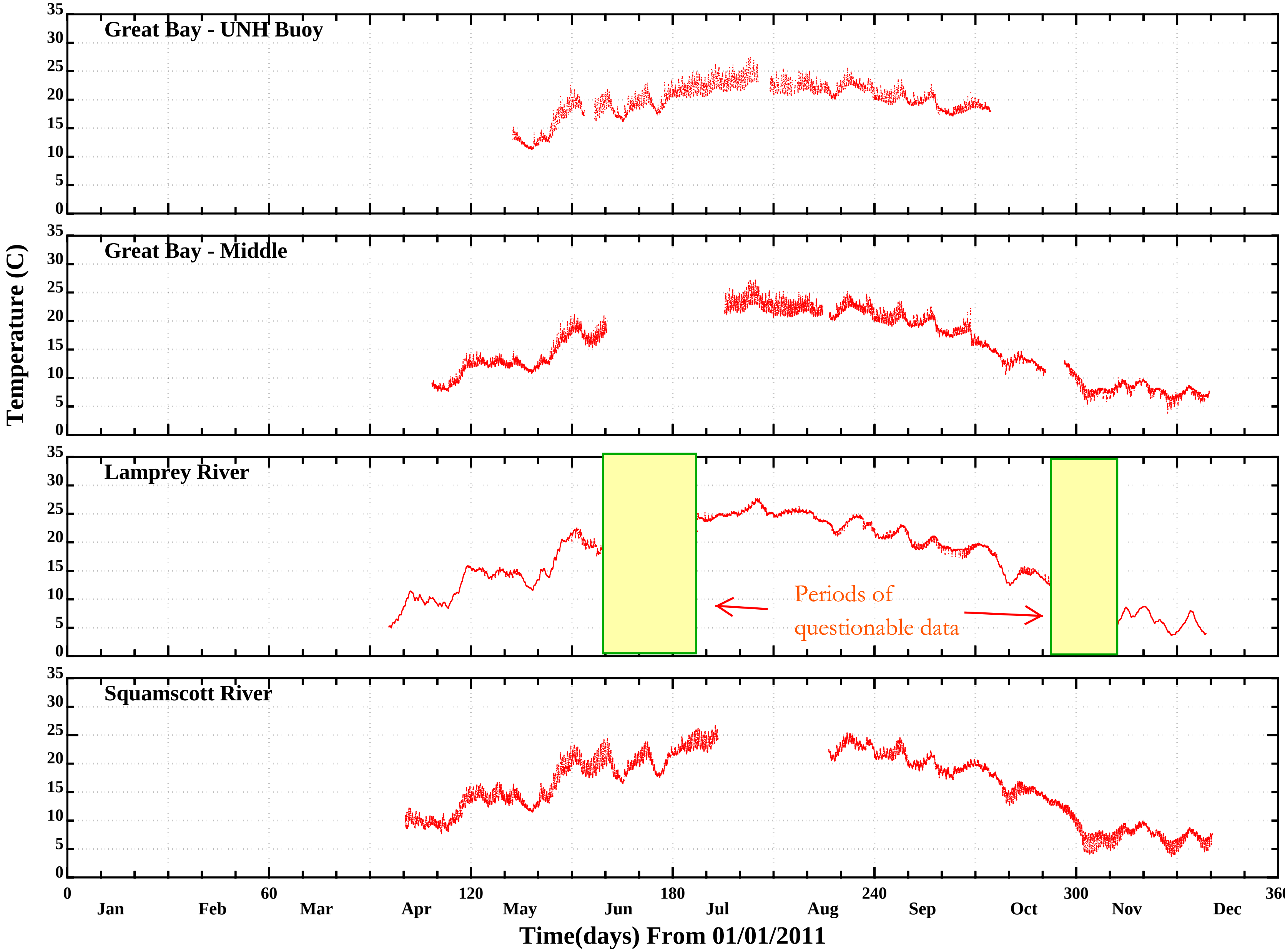

FIGURE 12. Observed Water Temperature Data at Monitoring Stations: 2011

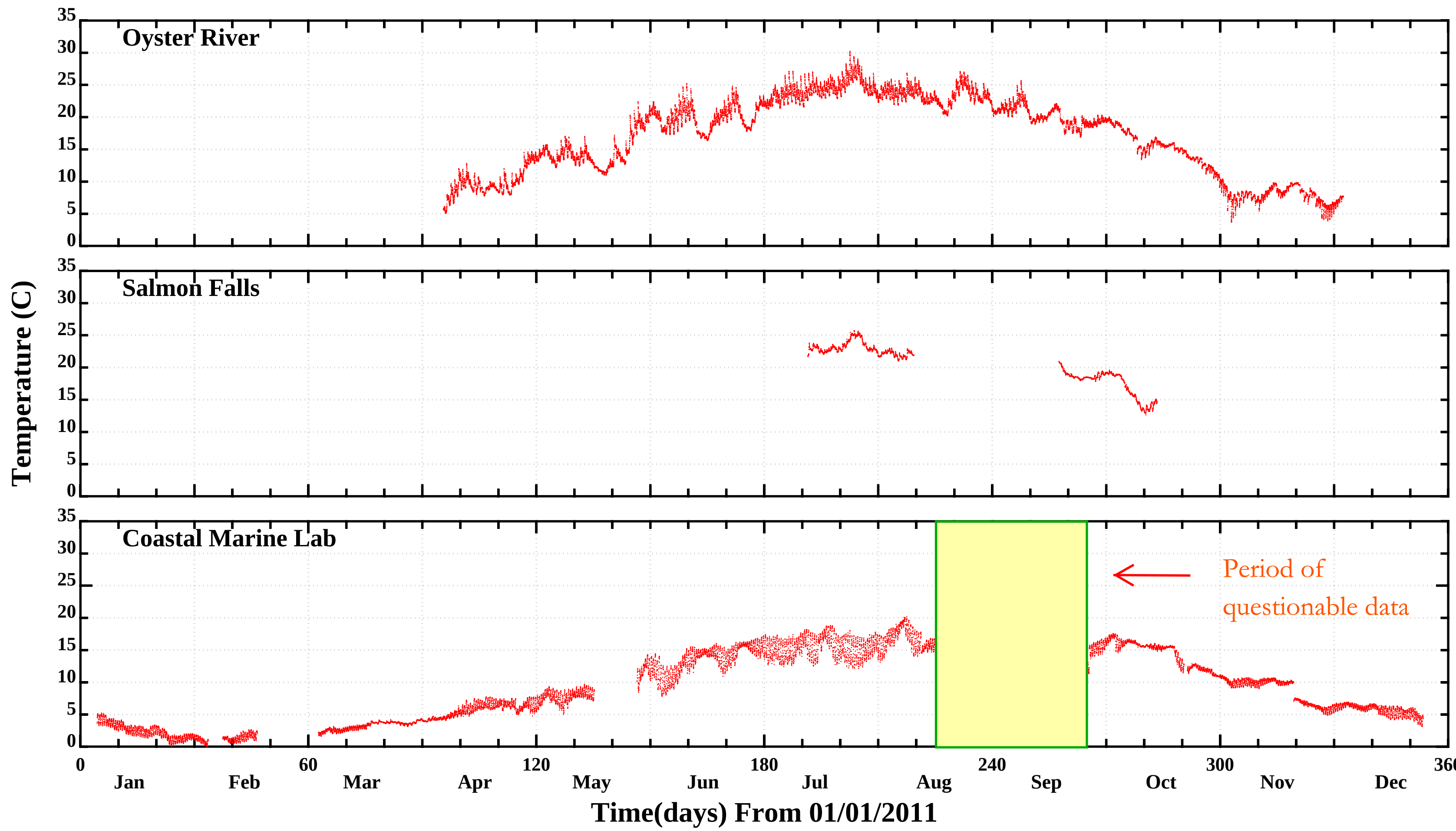

FIGURE 12. Observed Water Temperature Data at Monitoring Stations: 2011 (Cont.)

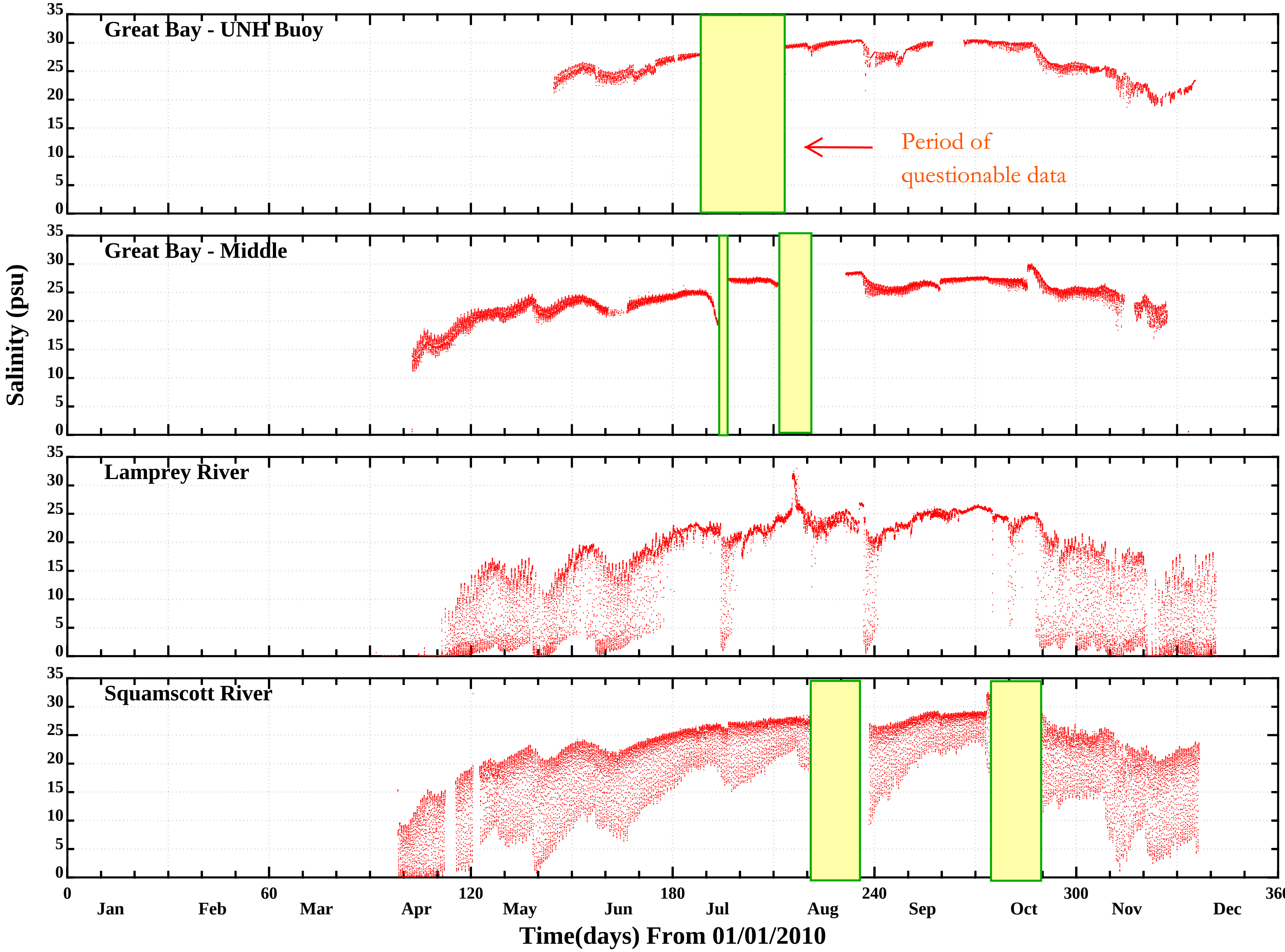

FIGURE 13. Observed Salinity Data at Monitoring Stations: 2010

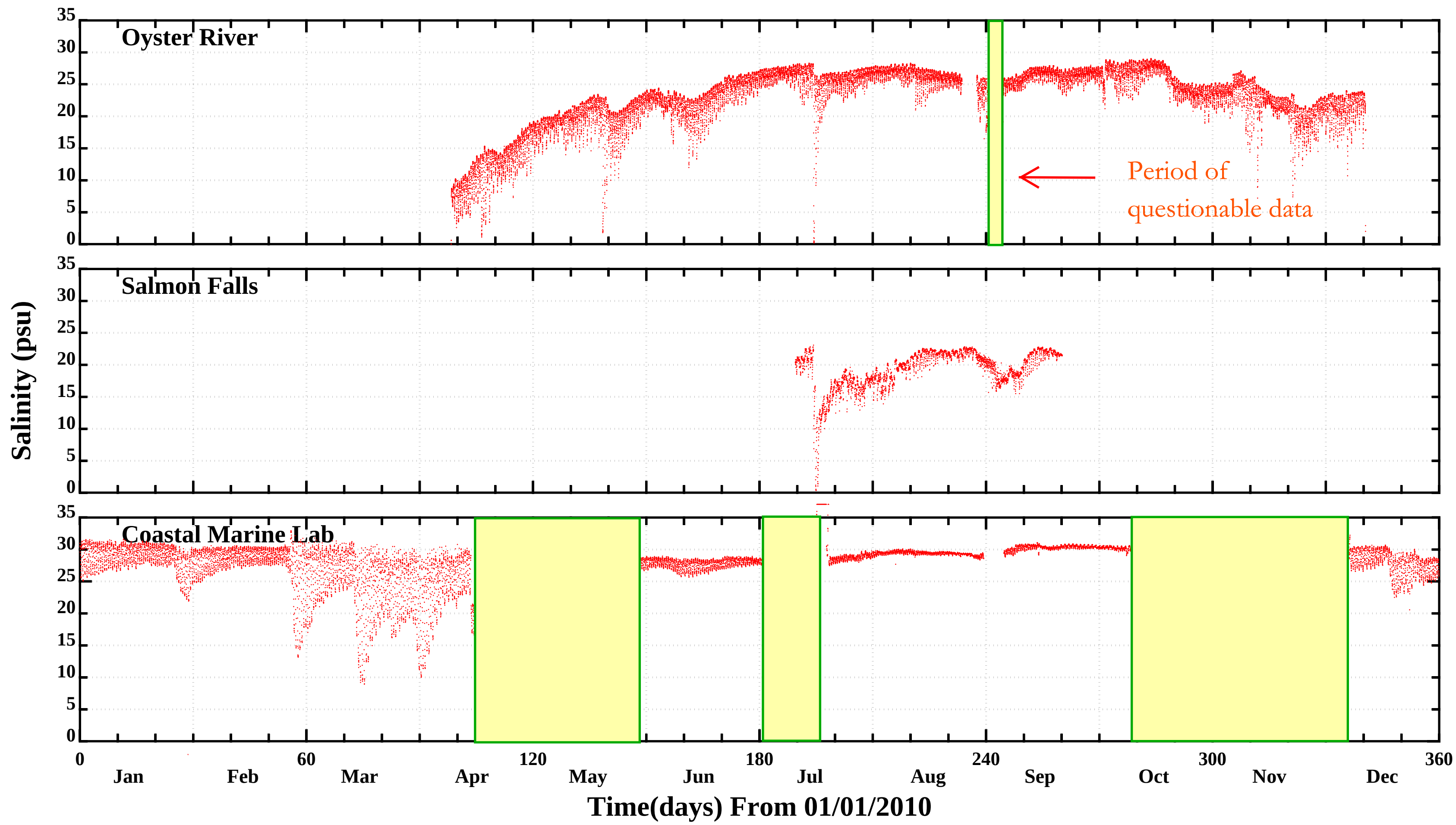

FIGURE 13. Observed Salinity Data at Monitoring Stations: 2010 (Cont.)

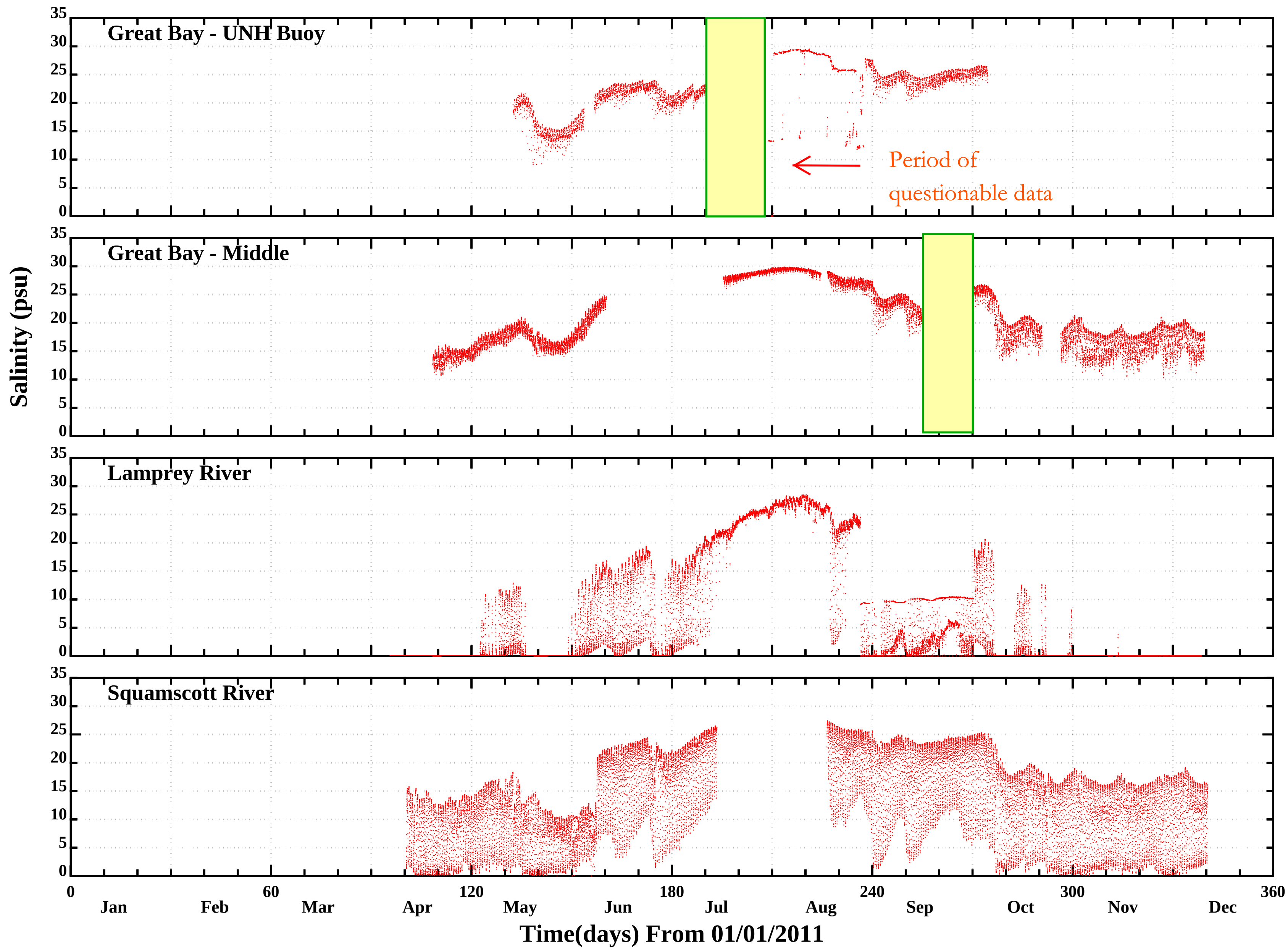

FIGURE 14. Observed Salinity Data at Monitoring Stations: 2011

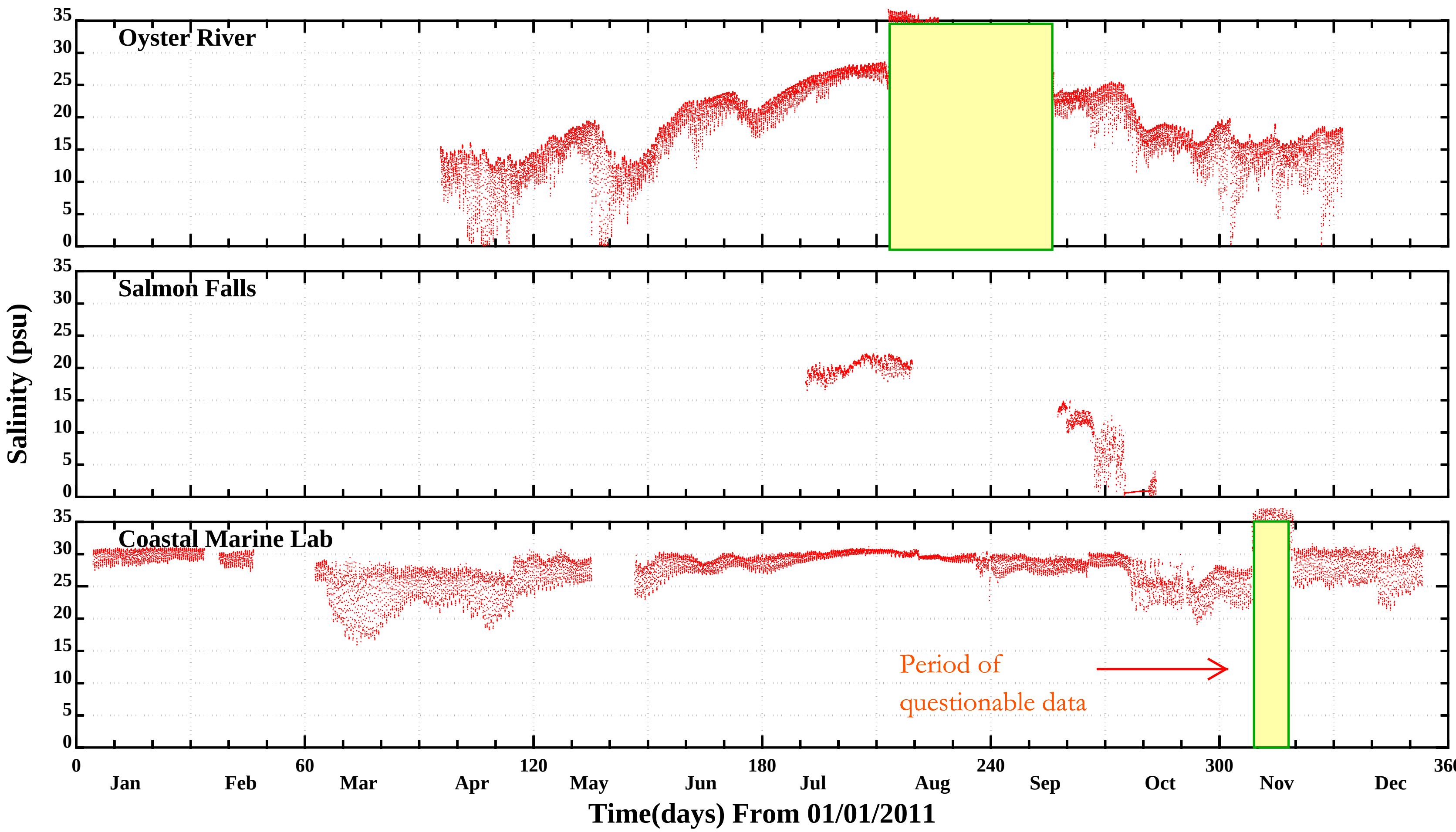

FIGURE 14. Observed Salinity Data at Monitoring Stations: 2011 (Cont.)

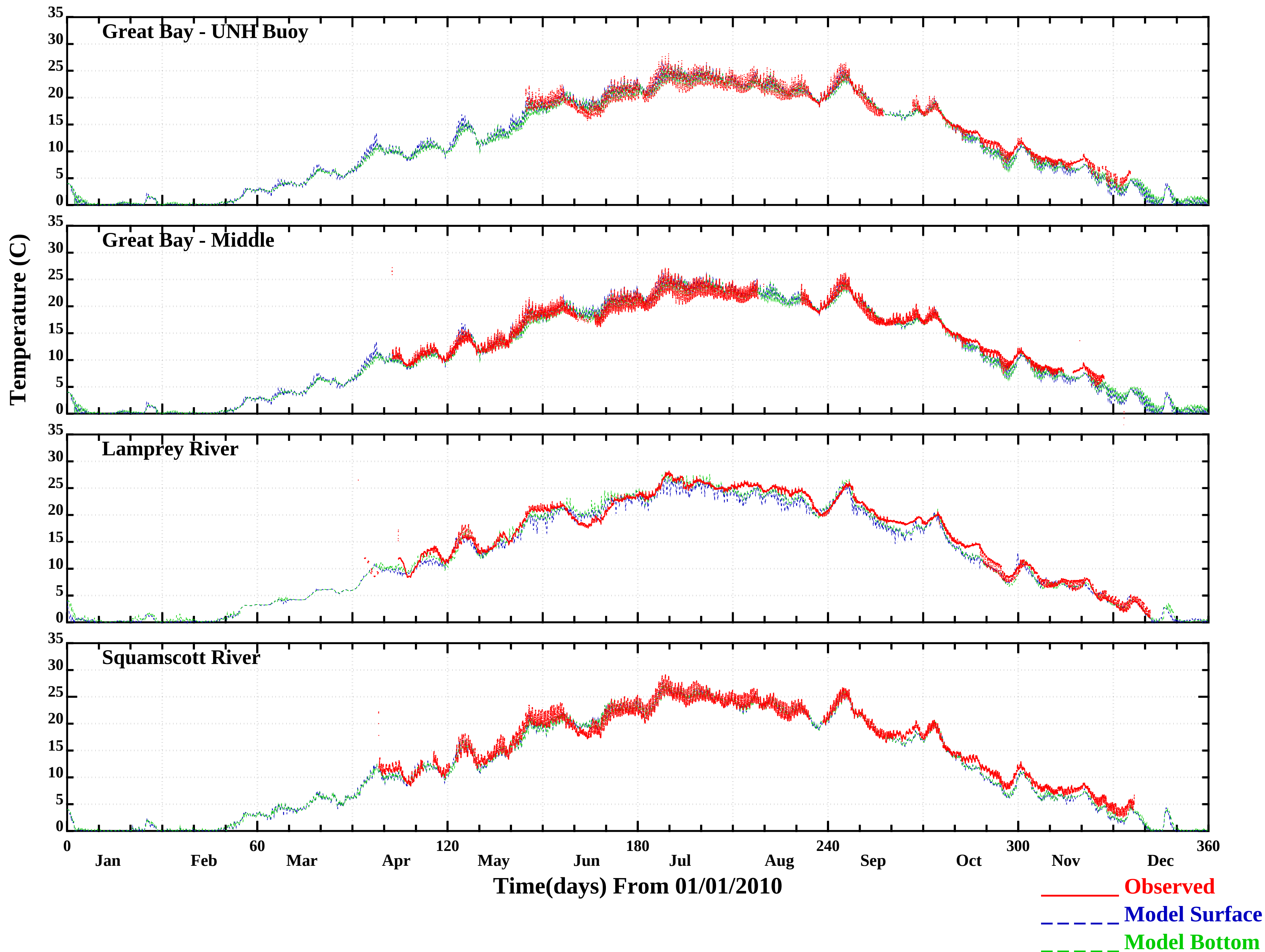

FIGURE 15. Comparison of Observed and Computed Water Temperature: 2010

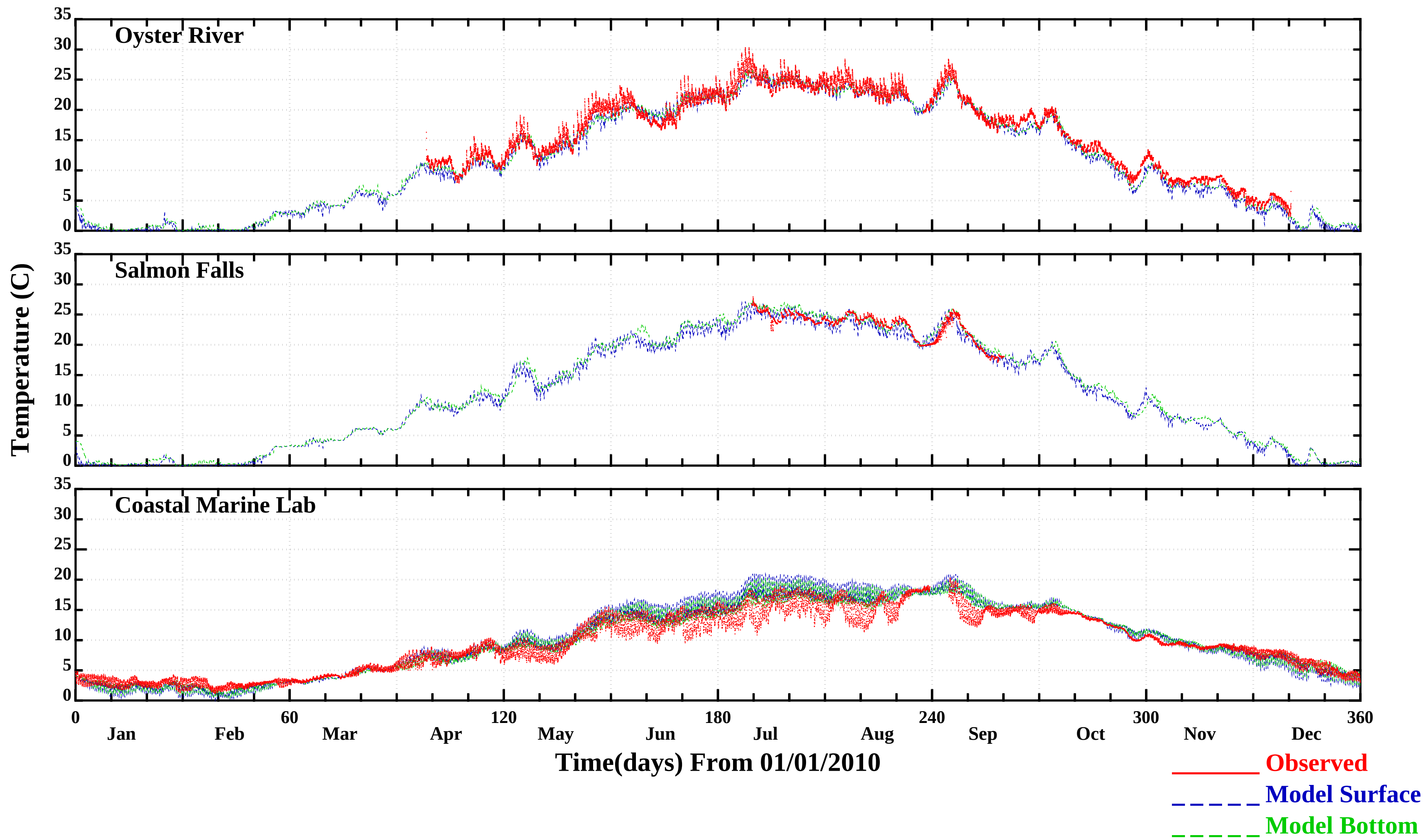

FIGURE 15. Comparison of Observed and Computed Water Temperature: 2010 (Cont.)